

FINAL REPORT
on
THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
INTERDISCIPLINARY STUDIES IN SPACE TECHNOLOGY
AT THE UNIVERSITY OF KANSAS

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Submitted by

B.G. Barr, Director
The University of Kansas Space Technology Center
Principal Investigator

September 1974

Final report on work completed
under NASA Grant NGL 17-002-001.

THE UNIVERSITY OF KANSAS CENTER FOR RESEARCH, INC.

Space Technology Center—Nichols Hall
2291 Irving Hill Drive—Campus West
Lawrence, Kansas 66045





THE UNIVERSITY OF KANSAS CENTER FOR RESEARCH, INC.

2385 Irving Hill Drive—Campus West Lawrence, Kansas 66045

29 October 1974

Mr. E. R. Redding
Code P
Office of University Affairs
National Aeronautics & Space Administration
Washington, D. C. 20546

Dear Ed:

Please find enclosed two copies of the final report on NASA Grant NGL 17-002-001, "Interdisciplinary Studies in Space Technology". I have prepared the report in accordance with the suggestions made during our recent conversation. I hope that it provides all the information you need concerning the program. I think you can see from the report that the grant has had a tremendous effect on our programs at the University of Kansas. We are extremely grateful for the support provided by the National Aeronautics & Space Administration and look forward to a continuing association mutually beneficial to both organizations.

Sincerely,

B. G. Barr
Executive Director

BGB:sja

enclosures

PS: We are sending five copies to the NASA Scientific and Technical Information Facility in College Park, Maryland.

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ABSTRACT

The NASA Interdisciplinary Studies in Space Technology Grant first awarded to The University of Kansas in 1961 has supported space research in thirty disciplines throughout the University. During the ensuing years the Grant has supported over eighty faculty members, approximately eighty graduate students and resulted in over one hundred and fifty publications with forty-one students receiving doctoral degrees and thirty-three masters degrees being awarded.

The growth in research efforts resulting from the Grant led to the construction of a NASA-funded interdisciplinary space research facility on the University of Kansas campus. Programs initiated under the Grant have led to significant research contributions in space research, development, and applications.

Final Report
on
The National Aeronautics and Space Administration
Interdisciplinary Studies in Space Technology
at The University of Kansas

In 1962, The University of Kansas appointed a special committee to encourage interdisciplinary activity in space research. The Committee on Space Science and Technology maintained a continuing review of University involvement in the space effort and furnished guidance to improve the University's capacity for direct contribution to the space effort while continuing to enhance the educational opportunities of the young people attending The University of Kansas.

The duties of the Committee were:

- 1) To advise and represent the University at the interdisciplinary level.
- 2) To foster and encourage study and research in space sciences and technology, including the provision of direct assistance for the initiation of research and for such activities as seminars, institutes, and lectures on the campus.
- 3) To prepare longer-range plans for the University's activities in space science and technology.
- 4) To cooperate with others in the stimulation of public and industrial interest in space technology in the midcontinent region.

Shortly after the establishment of the Committee on Space Science and Technology, the University received the first of several step-funded sustaining University program grants awarded by NASA to strengthen the scientific and technological competence of the University in areas of interest to NASA. During the period 1962-1974, the grant provided a focal point of aerospace activities at the University and has been a significant and crucial factor in the development of several groups at the University to a position of leadership in the aerospace and earth observation fields. (See pp. 46-104, RESEARCH, The University of Kansas Center for Research - Attachment 1).

The funds granted to the University by NASA for the broad support of research activities in space-related topics were administered by the Space Science and Technology Executive Committee composed of the Associate Dean of Faculties for Research, the

Chairman of the Department of Comparative Biochemistry and Physiology, an Associate Dean of the Graduate School, the Executive Director of the Center for Research, Inc., and the Dean of the School of Engineering and Architecture who served as Committee Chairman. During the period of the grant the composition of the committee remained essentially as shown in Table 1; thus contributing to continuity of operation.

The committee administered the Sustaining University Program (S.U.P.) funds following guidelines and procedures which encompassed the following:

- 1) Top priority was given to interdisciplinary studies which employed the talents of researchers from various science and engineering departments on problems at the interface between fields.
- 2) Research was supported which promised to develop a latent competence that was not maturing fast enough to stay abreast of the advancing frontiers of space knowledge.
- 3) Campus-wide involvement in space science and applications was simulated by supporting:
 - a. interdisciplinary seminars;
 - b. visiting lecturers;
 - c. travel to NASA centers and space symposia by researchers;
 - d. research support to new faculty members who could supply needed competence to a team; and
 - e. short courses on campus, by NASA personnel, on the state of the art in various fields; instrumentation, structures, propulsion, etc.
- 4) Ways were sought to use the space research efforts of the University staff for the economic, social and general well-being of the state and nation. (Appendix 1)

During the past decade The University of Kansas has established its role in the space community and has expanded its commitment to the field of space science and technology. The University has contributed the competence and the interest of its faculty and students in the space-related disciplines, acting under the stimulus and support of the National Aeronautics and Space Administration.

The wide distribution of these interdisciplinary funds throughout the schools and departments of the University by K.U.'s Committee on Space Science and Technology has succeeded in producing a greater awareness of the omnipresence of space goals. Tendencies towards oversimplification of the space effort (into solely "rocket technology" or "astronomy", for example) have disappeared as investigators in the life sciences, earth sciences, behavioral sciences, and business have joined engineers, physicists, and chemists in research aimed at solving the challenges of space exploration.

TABLE 1

COMMITTEE AND ADVISORY PANEL ON SPACE SCIENCE AND TECHNOLOGY *

EXECUTIVE COMMITTEE

Chairman	Dr. William P. Smith, Dean, School of Engineering and Architecture
	Dr. William J. Argersinger, Jr., Vice Chancellor for Research and Graduate Studies
	Dr. Paul Burton, Chairman, Physiology and Cell Biology
	Mr. B. G. Barr, Executive Director, The University of Kansas Center for Research, Inc.
	Dr. Robert Ellermeier, Associate Dean, Graduate School

ADVISORY PANEL

	Dr. Edward L. Wike, Professor of Psychology
	Dr. Russell C. Mills, Associate Dean of Medical School
	Dr. Kurt Reissman, Professor of Medicine (Research in Space Physiology)
	Dr. Charles A. Reynolds, Associate Chairman, Department of Chemistry
	Dr. Ross E. McKinney, Professor of Civil Engineering
	Dr. R.R. Gatts, Chairman, Department of Mechanical Engineering
	Dr. Charles K. Warriner, Chairman, Sociology
	Dr. Francis Prosser, Associate Professor of Physics
	Dr. Hampton Shirer, Associate Professor, Comparative Biochemistry and Physiology, and Electrical Engineering
	Dr. Paul J. McCarthy, Professor of Mathematics
	Dr. William M. Merrill, Professor of Geology
	Dr. Delbert Shankel, Associate Professor of Microbiology

*Typical membership on Committee during period of S.U.P. grant.

The grant has funded 137 projects during the period of the grant (Appendix 2). The appended project titles indicate some of the ways that investigators in numerous disciplines have been involved in space-related research during the past decade. Many others have been made cognizant of space activities and interests through associations with these researchers and through lectures, seminars and symposia conducted by distinguished visitors to the campus.

The relevance of the program to the goals of NASA was emphasized both in calling for and reviewing applications for project support under the grant. Moreover, as interest and involvement in space topics became University-wide, a focusing of emphasis on a few areas of primary importance took place.

The Sustaining University Program support has, over the past several years, stimulated the growth of viable multidisciplinary space research at the University of Kansas. The thrust of this research has been increasingly applications oriented with broad interest developing in three general areas:

- 1) Remote sensing of earth resources,
- 2) Stability and control of light and general aviation aircraft, and
- 3) Response to the vibrations of aeronautical and space vehicles.

The organization of the space committee itself and the manner of reviewing the applications for NASA-University support communicated the interests, goals and abilities of many researchers far beyond their usual circles. Many more specific short-range benefits can be listed -- new research efforts, publications, "activation" of new investigators, graduate student involvement, participation in specific NASA programs -- but the impetus toward interdepartmental effort is expected to be the most profound long-range effect of the grant on research at The University of Kansas.

This cooperation between disciplines toward which the NASA research increasingly leads is exemplified by the departments of electrical engineering and geography, which after "seeding" by the institutional grant received major funding from NASA's Johnson Space Center, D.O.D. and others. Electrical engineers blended their state-of-the-art knowledge of remote sensing devices with the geographer's and geologist's ever-increasing ability to use more sophisticated tools. The geoscientists working in this environment designed more meaningful experiments to test the validity of hypotheses regarding earth surface phenomena, as, during the experimental design, they worked daily with engineers capable of understanding both the possibilities and limitations of available or conceivable sensors. Summaries of some of the current geoscience studies will be found in the appended report.

Each year as we reviewed the efforts brought about by the institutional grant, we perceived a sharper focus of goals and an expanded importance of the work

accomplished. The success of interdisciplinary seminars in promoting cooperative efforts and mutual interests was established. Research begun at the University has been tied into significant efforts elsewhere, as in the placement of several K.U. Ph.D. candidates at NASA's Langley Research Center for the conduct of their doctoral work. This has recently been expanded to include students at other NASA centers.

Many of the participants have benefited from associations with NASA scientists and engineers at the Manned Spacecraft Center, Marshall Space Flight Center, and the Langley and Ames Research Centers.

As indicated previously, the primary emphasis on the research supported by the Sustaining Grant after 1969 centered on the application of remote sensing to earth resources as extensions of work funded by MSC and Langley. Research on the socio-economic-political aspects of remote sensing also took place. A portion of the grant also augmented projects funded or proposed for funding by Langley Research Center. These related to improved control methods for light aircraft and human response to vibrations from aeronautical and space vehicles. The aircraft programs are now funded by NASA Langley and NASA Flight Research Center, Edwards, California.

The Committee also supported to the extent possible technical work related to earth observation studies which were recommended by the K.U. Remote Sensing Laboratory, but to date have not been funded by the NASA centers. These are basic pilot studies which would offer high potential for contribution to the overall NASA program but for programming reasons are not included in current contracts.

The Sustaining University Program, as implemented at K.U., has constantly increased the breadth of involvement of our research with the space effort and with the general well-being of the region and the nation. Moreover, the Space Committee has sought to use S.U.P. funds to lay the base for a continuing involvement, supported not only by NASA but by others who have benefited as the scope of our research has widened. For example, BETA Group (Business-Engineering Technological Applications, our technology-utilization program) continues to extend the findings of space research beyond the circle of those who have performed it to those with diverse areas of practical application. BETA was initiated under S.U.P., but is now largely supported by industry. And the Remote Sensing Laboratory, our outstanding interdisciplinary research group, originally received S.U.P. funds, but from that base has grown to encompass mission-oriented research for several major agencies including NASA, and is known as a "Center of Excellence" in remote sensing technology.

Extensive research capabilities as demonstrated in the sponsored research projects now underway at The University of Kansas were aided in their development by

the Sustaining Grant. A continuing relationship of research involvement is maintained through the Office of University Affairs in NASA's support of active research at the University.

The following paragraphs and attachments detail some of the on-going research which has resulted from the Sustaining Grant.

EARTH OBSERVATION STUDIES AT THE UNIVERSITY OF KANSAS

The University of Kansas has worked in conjunction with other universities and with federal agencies to determine ways in which observations of the earth's surface by aircraft and spacecraft can be used by agriculture and forestry interests, geologists and cartographers, by those concerned with water quality and hydrology and by mineral and oceanographic interests. This has been done under various contracts and grants from NASA, the Department of Agriculture, Department of Interior, the Army Topographic Laboratory, and the Office of Naval Research. These efforts have extended over a period of several years and have resulted in the development of considerable capability to process, interpret and apply data from sensors such as are being used on ERTS-1 and SKYLAB flights.

The high interest and potential of the K.U. investigators to use satellite remote sensed data suggested the submission, in early 1971, of coordinated multidisciplinary proposals from the researchers in the state. Investigators involved in agricultural, geographic and geologic feasibility studies which had been performed as elements of Remote Sensing Laboratory instrument contracts funded by NASA formed the nucleus of a group which outlined the Kansas Environmental Resources Study proposals (KERS).

The Kansas Environmental Resources Study (KERS) ERTS-1 program is now completing the following tasks. Additional work has been proposed for ERTS-II (or continuation of ERTS-I) funding on several of these tasks.

Data Processing Team

- | | |
|--------|---|
| Task 1 | Using of Feature Extraction Techniques for the Texture and Context Information in ERTS Imagery - Robert M. Haralick, Principal Investigator, University of Kansas |
| Task 2 | Interpretation and Automatic Image Enhancement Processing Facility - R.M. Haralick and G.L. Kelly, Principal Investigators, University of Kansas |

Agricultural Team

- | | |
|--------|---|
| Task 1 | Wheat: Its Water Use, Production, and Disease Detection and Prediction - E.T. Kanemasu, Principal Investigator, Kansas State University |
| Task 2 | Extraction of Agricultural Statistics from ERTS-1 Data of Kansas - S.A. Morain, Principal Investigator, University of Kansas |

Geoscience Team

- | | |
|--------|---|
| Task 1 | ERTS Study of Water Quality - H.L. Yarger, G.W. James, G.R. Marzolf, and J.C. Coiner, Principal Investigators, Kansas Geological Survey, University of Kansas and Kansas State University |
|--------|---|

Several SKYLAB projects were funded to use the data returned from the manned station. Also, expertise at the Remote Sensing Laboratory was utilized through contracts for the design and evaluation of an instrument used aboard SKYLAB. Specific projects and the principal investigators include:

Moore, R.K., "SKYLAB Radscat";

Moore, R.K., "S193 Development Support and Performance Evaluation," (NAS 9-13347);

Moore, R.K., "SKYLAB Microwave Oceanographic," (NAS 9-13356);

Yarger, H.L., "SKYLAB Study of Water Quality EREP Nr. 540-G-1," (NAS 9-13271);

Eagleman, J.R., E. Pogge, and R.K. Moore, "Detection of Moisture and Moisture Related Phenomena," (NAS 9-13273);

Moore, R.K., "Design Data Collection with Skylab/EREP Microwave Instrument," (NAS 9-13331); and

Moore, R.K. and W.J. Pierson (NY), "A Joint Meteorological, Oceanographic and Sensor Evaluation Program for Experiment S-193 on SKYLAB," (NAS 9-13642).

THE REMOTE SENSING LABORATORY

The University of Kansas Remote Sensing Laboratory (RSL) is an interdisciplinary group of researchers interested in the application of instruments carried on aircraft and spacecraft to sense features of the environment on the earth and other planets. Major emphasis is placed on the use of microwave radar as a sensor, but representations produced by cameras and multi-spectral scanners are also used in the UV, visible and infrared regions of the spectrum. In addition, applications of microwave radiometry are being studied.

The laboratory consists of three main research groups: (1) electrical engineers interested in the sensor and its interaction with the environment; (2) data processing specialists; and (3) users of sensor data including geographers, geologists, botanists, and civil engineers.

To effectively study the problems of remote sensing technique, activities of the Remote Sensing Laboratory are divided into four areas: (1) object-sensor interaction studies; (2) sensor system studies and development; (3) data processing studies; and (4) geoscience application studies.

The Remote Sensing Laboratory, recognized as a "Center of Excellence," has been successful in providing valuable research progress in the area of earth resources. Some of the research areas are listed below:

- Multi-image correlation systems study;
- Theoretical study of a sea clutter model;
- Controlled surface acoustic simulators;
- Sensitivity enhancement and earth sensing satellites;
- Radar scatterometry measurements;
- Broad spectrum imaging radar;
- Acoustic simulation of electromagnetic imaging systems;
- Spectral location and variability of land-use information from space photography;
- Space photography in the detection of transportation networks;
- Agricultural land-use mapping with radar imagery;
- Crop-type discrimination with color and color-infrared photography;
- Side-looking airborne imagery lineament analysis;
- Geoscience evaluation of multi-frequency radar imagery; and
- Geoscience evaluation of multi-polarization radar imagery.

SATELLITE APPLICATIONS LABORATORY

The Kansas Environmental and Resources Studies (KERS) program has greatly contributed to the technological base and has enlarged the capability of the University of Kansas for performing "The Application of Satellite Remote Sensing to Resource Management and Environmental Quality Concerns in Local, State and Regional Agencies."

The KU Applications Program is based on a sustained multidisciplinary approach to specific projects in state and local agencies. The program involves workshops on remote sensing designed to introduce state and local agency personnel to the latest state-of-the-art sensing and interpretation techniques employed by NASA and its contracting agencies. The contacts and associations which develop from the workshops allow the program director and coordinator to identify those agencies that can apply satellite and aircraft derived data to their agency needs. The program is iterative in nature with the workshops identifying agency interest and leading to individual contracts to explore the use of remotely sensed data. These contacts then lead to further discussion and meetings with operational personnel within the agencies to establish action-oriented projects in which Space Technology Center and agency personnel work cooperatively to develop the data which will aid the decision maker.

Many projects have been completed by the applications scientists which have shown positive results in aiding the agencies involved. The following projects are listed as examples:

- 1) selection of a route for a scenic parkway;
- 2) policy development on open land use;
- 3) policy related to urban development;
- 4) a major reservoir project by a governor's staff;
- 5) control tactics and damage assessment during flooding conditions on the Kansas and Missouri rivers; and
- 6) initiating a program of habitat inventory by remote sensing by the Kansas Forestry, Fish & Game Commission.

FLIGHT RESEARCH LABORATORY

Flight Research Laboratory personnel have a primary interest in the technology of winged vehicles, with a special emphasis on light and general aviation aircraft. A significant level of research activity is being conducted in the laboratories, and faculty are serving as consultants to Beech, Bell Helicopter, Boeing, Cessna, Lear Jet, and the FAA.

A major research facility, a fixed-base visual and instrument flight simulator, is now in operation. This greatly enhances the ability to solve problems involving pilot response, cockpit and control system design, handling qualities, and stability augmentation.

Other facilities for research include a subsonic wind tunnel with 6-component balance and automated data readout, a structural test laboratory, instrumentation laboratory, and a Cessna 172 and Cessna Cardinal for flight test work.

Research is now being conducted in the areas of light airplane design, gust alleviation, separate surface stability augmentation, aerodynamic analysis of flexible wings, high lift systems, and direct lift control.

Graduate students continue to play a major role in this research activity with undergraduates often supplying excellent assistance. Cooperative efforts of the Doctor of Engineering program and several NASA research centers has greatly enhanced the doctoral program in aerospace engineering.

TECHNOLOGY UTILIZATION--BUSINESS AND ENGINEERING
TECHNICAL APPLICATIONS (BETA) GROUP

Established in 1965 with the aid of the S.U.P. Grant, the BETA Group of the Center for Research, Inc., has expanded and sought to achieve its goal: the dissemination and use of information resulting from space-related research.

At first, the technical information service of the BETA Group was provided at no cost to industry in the Midwest. When the original NASA grant had been exhausted, the decision was made to continue the service on a non-profit basis by charging companies for the time, material, travel and overhead costs involved. Now, the BETA Group is assisting industry with a broad range of technical problems by utilizing every available source of information.

Undergraduate and graduate students with the ability and the initiative to help industry solve its many and varied problems are encouraged to become Applications Engineers with the BETA Group. Members of this team of students travel throughout the Midwest visiting companies and informing them of the literature search, manufacturers' survey, and other services which are available at low cost through the BETA Group. When a problem is referred to the BETA Group, the most qualified engineer is assigned to the project, informed of the project requirements, and expected to complete the project within the prescribed time limit. This engineer is responsible for the project from the time it is assigned until payment is received for the final results. The student thus becomes better acquainted with using library facilities, contacting prominent people in many fields, accounting for costs involved with a project, preparing formal engineering and business reports, following basic administrative procedures, and billing for services rendered. Industry, in return, receives technical information about its problems at a cost substantially lower than other sources of similar information.

The BETA operation has been widely recognized and a contractual agreement was signed with the United Nations Industrial Development Organization in Vienna in 1971. This agreement has brought various industrial problems from developing nations to the BETA group for study.

The expertise developed by student engineers in the field of information retrieval permits the BETA Group's Technical information service to disseminate information to industry both regionally and internationally, to assist individuals with technical problems, and to give students practical experience in managing research projects.

DOCTOR OF ENGINEERING PROGRAM

A cooperative agreement was reached between Dr. Kenneth Lenzen of the University of Kansas and Dr. John DuBerg of NASA Langley for the research and writing of Ph.D. theses in the early years of the Sustaining Grant. This cooperation extended over the ensuing years and four Ph.D. students completed their dissertations based on research conducted in various areas at Langley.

With the introduction of the Doctor of Engineering program in interdisciplinary areas, the agreement originally reached was transferred to this program. One Doctor of Engineering degree has been completed at Langley after the program transfer. Two students are now working at Langley and a proposal has been submitted for a third student to begin at NASA Langley.

This program has been so successful that it has been enlarged to include all the NASA research centers. Students should be participating at Lewis Research Center, Ames Research Center, and the NASA Flight Research Center at Edwards in the Fall of 1975.

The institution and successful continuation of this cooperative program is a result of the impetus given to KU research programs by the Sustaining Grant.

APPENDIX 1

GOVERNOR'S LETTER OF SUPPORT

STATE OF KANSAS



OFFICE OF THE GOVERNOR

State Capitol
Topeka

ROBERT B. DOCKING
Governor

November 8, 1973

Mr. B. G. Barr, Director
The University of Kansas
Space Technology Center
2291 Irving Hill Drive - Campus West
Lawrence, Kansas 66044

Dear Bill:

Pat Burnau showed me your recent note and the enclosed copy of your letter to Chancellor Dykes reviewing your success in assisting state and local governments with the services available at the University of Kansas Space Technology Center.

I am pleased our office has been of assistance to you. Your program has proved to be beneficial to many state agencies. Thank you for your help. Please never hesitate to contact me at any time.

With every good wish.

Yours sincerely,

A handwritten signature in cursive script, appearing to read "Bob", written over a horizontal line.

Robert Docking
Governor of Kansas

RD/jj

cc: Chancellor Archie Dykes
University of Kansas
Lawrence, Kansas 66044

APPENDIX 2

RESEARCH PROJECTS AND PRINCIPAL INVESTIGATORS SUPPORTED

RESEARCH PROJECTS/PRINCIPAL INVESTIGATORS
SUPPORTED UNDER GRANT NGL 17-002-001

CRINC NUMBER	PRINCIPAL INVESTIGATOR	DEPARTMENT	TITLE
0301-821	Samson/Balfour	Physiology & Cell Biology	Brain Energy Levels
0302-821	Shankel/Akagi	Microbiology	Electron Transport-Radiation
0303-821	Moore	Electrical Engineering	Wave-Scattering
0304-821	Nahman/Kurata	Chemical & Petroleum Engineering	Viscosity-Dielectric
0305-821	Rose	Mechanical Engineering	Phosphorus Metal Coating
0306-821	Unz	Electrical Engineering	Electrical Phenomena
0307-821	Tiedemann	Mechanical Engineering	Low-Cycle Fatigue
0308-821	Hoecker/Shaw/Friesen	Radiation Biophysics	Dosimetry
0309-821	McCluggage	Sociology	Small Group Study
0310-821	Yu	Civil Engineering	Mechanics of Blood Flow
0311-821	McKinney	Civil Engineering	Algae Respiration
0312-821	Srinath		Three-Dimensional Photoelasticity
0313-821	Mahayni	Civil Engineering	Stability of Shells
0314-821	Magnus		Satellite Orbits
0315-821	Zorski		Thermo-Elasticity
0316-821	Roofe/Beck	Physiology & Cell Biology	Blood Distribution at Zero "G"
0317-821	Enoch	Physics & Astronomy	Statistical Mechanics - Thermo- dynamic Equilibrium; Transport Phenomena
0401-821	Chu	Chemistry	Helium Opalescence
0402-821	Burgstahler	Chemistry	Hydrocarbon Synthesis
0403-821	Rowland	Chemistry	Molecule Collisions
0404-821	Adams	Chemistry	Free Radical Ions
0410-821	Schowen	Chemistry	Silane Decompositions
0411-821	Harmony	Chemistry	Microwave Spectroscopic Studies

PROJECTS/PRINCIPAL INVESTIGATORS - Page Two

CRINC Number	PRINCIPAL INVESTIGATOR	DEPARTMENT	TITLE
0412-821	Kitos	Biochemistry	Metabolic Pathways
0413-821	Mertes	Pharmaceutical Chemistry	Radiation Protection
0415-821	Mohn	Anatomy	Cooperative Studies with Erythropoietin
0416-821	Leaders	Pharmacology	Cell Growth
0417-821	Mesler	Chemical & Petroleum Engineering	Cavitation
0418-821	Bates	Engineering Mechanics	Atmospheric Turbulence
0419-821	Mahayni	Engineering Mechanics	Thermal Stresses
0420-821	Akashi	Engineering Mechanics	Human Controller
0421-821	Linzell	Engineering Mechanics	Mechanical Behavior of Metals
0422-821	Zagustin/Lenzen	Engineering Mechanics	Dynamic Buckling of Shells
0424-821	Nahman	Electrical Engineering	Transit Times
0425-821	Moore	Electrical Engineering	Wave-Scattering
0426-821	Warfield	Electrical Engineering	Memory Simulation
0427-821	Bauleke	Engineering Mechanics	Impurities in Mica
0428-821	Rose	Engineering Mechanics	Atomic & Electronic Heat
0429-821	Leone	Zoology	Biological Systems
0432-821	Sword	Bacteriology	Genetic Factors
0433-821	Akagi	Bacteriology	Life Processes
0434-821	Thompson	Botony	Ultrastructure
0435-821	Elbel	Physical Education	Pulse Reaction
0436-821	Bussell	Microbiology	Nonionizing Radiation
0437-821	Adams	Chemistry	Free Radical Ions
0438-821	Rose	Engineering Mechanics	Atomic & Electronic Heat
0439-821	Nahman	Engineering Mechanics	Blackout Phenomenon in Miniature Tubes

PROJECTS/PRINCIPAL INVESTIGATORS - Page Three

CRINC Number	PRINCIPAL INVESTIGATOR	DEPARTMENT	TITLE
0440-821	Willems	Civil Engineering	Collapse Loads of Thin Rectangular Plates
0441-821	Moore	Electrical Engineering	Wave-Scattering
0442-821	Freeman	Microbiology	DME Simulation
0601-821	Akagi	Microbiology	Inorganic Sulfur Compounds
0602-821	Mesler	Chemical & Petroleum Engineering	Leidenfrost Phenomenon
0603-821	Bauleke	Mechanical Engineering	Strengthening of Metals
0604-821	Dusanic	Microbiology	Antigenic Properties of Isozyme
0605-821	Schowen	Chemistry	Silicone Decomposition
0606-821	Ananthanarayanan	Mechanical Engineering	Iron-Copper Powder Magnets
0607-821	Shankel	Microbiology	Studies of Azotobacter Species
0608-821	Swift	Chemical & Petroleum Engineering	Insulation for Cryogen Storage
0609-821	Shah	Mathematics	Non-Linear Diff. Equations
0610-821	Shirer & Fitch	Electrical Engineering/CBP	Central Recording of Biol Data
0611-821	Mertes	Pharmaceutical Chemistry	Radiation Protective
0612-821	Wright	Psychology	Psychological Hibernation
0613-821	Barr/Gatts/Saunders	Mechanical Engineering/ Business	Technology Utilization (BETA)
0614-821	Moore	Electrical Engineering	Wave-Scattering
0615-821	Talley	Electrical Engineering	Semiconductor Surfaces
0616-821	Daugherty	Electrical Engineering	Wide Band Frequency Multiplier
0617-821	Adams	Chemistry	Fundamental Studies of Biochemical Energy Conversion Systems
0618-821	Dusanic	Microbiology	Ionizing Radiations
0801-821	Schowen	Chemistry	Analysis of Plates of Variable Thickness
0802-821	Willems	Civil Engineering	Stability of Stiffened Plates

PROJECTS/PRINCIPAL INVESTIGATORS - Page Four

CRINC Number	PRINCIPAL INVESTIGATOR	DEPARTMENT	TITLE
0803-821	Elbel	Physical Education	Telemetering Pulse Rates of Men During Exercise
0804-821	Lal	Pharmacy	Behavioral Effects of Drugs Sensory Stimulation
0805-821	Gilles	Chemistry	Seminar
0806-821	Leaders/Gilles/Norton	Chemistry/Pharmacy	Cardiovascular Responses Zer-G
0807-821	Lenzen	Engineering Mechanics	Free Vibrational Frequencies and Corresponding Mode Shapes of an Axisymmetric, Homogenous, Isotropic Hollow Torus
0808-821	Barr/Gatts/Saunders	Engineering Mechanics	Information Retrieval (BETA)
0809-821	Warfield	Electrical Engineering	Generating Data on High-Speed Random Bit Source
0810-821	Kaesler	Geology	Numerical Taxonomy in Paleontology
0811-821	Willems	Civil Engineering	Plates of Variable Thickness
0812-821	Kohlman	Mechanical and Aerospace Engineering	Engineering Development Parafoil
0813-821	Talley	Electrical Engineering	Study of Lithium-Drifted Semiconductor Junctions
0814-821	Leone	Zoology	Thermal Denaturation Profiles of DNA
0815-821	Himes	Biochemistry	Biochemistry of a Thermophile
0816-821	Shirer/Fitch	Zoology/Electrical Engineering/Biochemistry	Natural Environmental Factors in Behavior of the Opossum, Raccoon and Striped Skunk
1001-821	Freeman	Microbiology	Studies on the Molecular Basis of Antibody Formation
1002-821	Gilles	Chemistry	Work in High Temperature Chemistry
1003-821	Barr	Mechanical Engineering	Continuation of BETA Project
1004-821	Faiman	Pharmacy	Effect of Oxygen Tension on the Kinetics of Catecholamine Levels in the Brain and Heart
1005-821	Schowen	Chemistry	Catalytic Mode and Efficiencies in Formation and Cleavage of Carbon-Carbon Bond

PROJECTS/PRINCIPAL INVESTIGATORS - Page Five

CRINC Number	PRINCIPAL INVESTIGATOR	DEPARTMENT	TITLE
1006-821	Lal	Pharmacy	Effects of Environmental Sensory Stimuli on Biochemical and Behavioral Actions of Drugs
1007-821	Leaders/Norton	Pharmacology	Cardiovascular Responses Under "Zero-g" Conditions Simulated by Reducing Sensory Input
1008-821	Simonett/Dellwig	Geography/Geology	Studies on the Geoscience Value of Radar Imagery
1009-821	Anderson	Geology	Criteria for Recognition of Altered Ignimbrites
1201-821	Culvahouse	Physics	Study of Radiation Damage in Solids by Means of Electron Nuclear Double Resonance and Other Techniques
1202-821	Beard	Physics	Study of Extraterrestrial Contributions to the Magnetic Environment of Trapped Radiation and the Consequent Motion of Trapped Radiation in this Environment
1203-821	Anderson	Geology	Criteria for Recognition of Altered Ignimbrites
1204-821	Gilles/Schowen	Chemistry/Physics	Chemical Physics Seminar
1501-821	Culvahouse/Friauf	Physics	Study of Radiation Damage in Solids By Means Of Electron Nuclear Double Resonance and Other Techniques
1502-821	Samson	Biochemistry/Physiology	Biogenic Amines and Central Nervous System Stress
1503-821	Gilles	Chemistry	High Temperature Physical Chemistry
1504-821	Gilles	Chemistry	Seminar
1505-821	Schowen	Chemistry	Chemical Biology Seminar
1506-821	Barr	University Wide	Honorarium for Visiting Lecturers and Travel To Space Center
1701-821	Friauf/Zeller	Physics	Study of Radiation Damage in Solids By Means of Electron Nuclear Double Resonance and Other Techniques
1702-821	Samson	Comparative Biochemistry and Physics	Biogenic Amines and Central Nervous System Stress
1703-821	Gilles	Physics	High Temperature Physical Chemistry
1704-821	Christofferson	Chemistry	Chemical Physics Seminar

PROJECTS/PRINCIPAL INVESTIGATORS - Page Six

CRINC Number	PRINCIPAL INVESTIGATOR	DEPARTMENT	TITLE
1705-821	McChesney	Botany	Chemical Biology Seminar
1706-821	Barr	University Wide	Honorarium for Visiting Lecturers and Travel To Space Center
1707-821	Wike	Psychology	Human Response to Vibration
1708-821	Trank	Physiology/KU Med Center	Human Response To Vibration
1709-821	Kanet/Ketzel	Political Science	Political and Legal Implications of Remote Sensing Techniques
1801-821	Culvahouse/Friauf	Physics	Study of Radiation Damage in Solids by Means of Electron Nuclear Double Resonance and Other Technique
1802-821	Zeller	Physics	Radiation Damage Research
1803-821	Beard	Physics/Astronomy	The Cumulative Interplanetary Dust Concentration on the Lunar Surface
1804-821	Christofferson	Chemistry	Chemical Physics Seminar
1805-821	Kitos	Biochemistry	Chemical Biology Seminar
1806-821	Barr	University Wide	Honorarium for Visiting Lecturers and Travel To Space Center
1807-821	Schira	Painting and Sculpture	Remote Sensing of Visual Environment
1808-821	Harnapp	Geography	Remote Multi-Spectral Sensing for Tropical Land Use Mapping
1809-821	Kanet	Political Science	Political and Legal Implications of Remote Sensing
1811-821	Moore	Electrical Engineering	Multispectral Camera Cluster
1812-821	Christofferson	Chemistry	Graphics Techniques in Molecular Quantum Mechanics
1813-821	Adams	Chemistry	Behavioral Shuttle-Box
1814-821	Gilles	Chemistry	The Effect of Screw Dislocations on the Mechanism of Vaporization of High-Temperature Crystalline Materials
1815-821	Lenzen	Civil Engineering	Human Response To Vibrations
1816-821	Cross, et al	Systematics & Ecology	Comprehensive Ground Truth Studies of High Level Earth Observations

PROJECTS/PRINCIPAL INVESTIGATORS - Page Seven

CRINC Number	PRINCIPAL INVESTIGATOR	DEPARTMENT	TITLE
2001-821	Hierl	Chemistry	Chemical Physics Seminar
2002-821	Kitos	Biochemistry	Chemical Biology Seminar
2003-821	Zeller	Geology	Radiation Chemistry of Upper Atmosphere
2004-821	Schira	Painting & Sculpture	Investigation into the Complexities of Visual Space Environment
2005-821	Kanet/Ketzel	Political Science	Political and Legal Implications of Remote Sensing
2006-821	Lenzen	Civil Engineering	Human Response To Vibrations
2007-821	Barr	University Wide	Honorarium for Visiting Lecturers and Travel to Space Center
2008-821	Bearse/Prosser/ Fiorman	Physics	Purchase of High Resolution X-Ray Detector for Earth Observation Studies of Natural History Reservation and Vicinity
2009-821	Adams	Chemistry	Behavioral Shuttle-Box
2011-821	Haralick/Sedlows	Electrical Engineering/ Computer Science	Pattern Recognition...
2201-821	Moore/Holtzman	Electrical Engineering	Modification of Weather Radar To SLAR Configuration
2202-821	Schira	Painting & Sculpture	Investigation into the Complexities of a Visual Space Environment
2203-821	Ulaby	Electrical Engineering	Remote Sensing Study of Changes in Vegetation Reflectance with Stress
2204-821	Laird	Political Science	Remote Sensing: Its Uses and Its Potential For the Social Sciences
2205-821	Dellwig	Geology	Study of the Utilization of SLAR As A Mapping Tool
2206-821	Schowen	Chemistry	Automated Spectrophotometric Device
2207-821	Barr	University Wide	Honorarium for Visiting Lecturers and Travel To Space Center
2208-821	Haralick	Electrical Engineering	Completion of Computer/Language Project
2209-821	Barr/Walters	Mechanical Engineering	Purchase of the Bausch and Lomb Zoom Transfer Scope and The A-28 Stabilized Aerial Camera Mount
2210-821	Ulaby	Electrical Engineering	Mapping Vegetation Damage and Heavy Metal Concentration in the Soil of the New Lead Belt of Missouri

APPENDIX 3

PUBLICATIONS RESULTING FROM SUPPORT

PAPERS RESULTING FROM SUPPORT
OF GRANT NGL 17-002-001

CRINC Number	PRINCIPAL INVESTIGATOR	PAPERS/EXHIBITIONS
0302-821	Shankel	Final Report to the NASA Committee Project, Electron Transport 30B, November 11, 1963
0304-821	Nahman	Final Report: The Determination of the Macroscopic Viscosity of the Light Hydrocarbons by Means of Electrical Dielectric Constant Studies
0306-821	Unz	Fourier Transform Methods for Analyzing Nonuniform Arrays; Proc. IEEE, vol. 53, No. 2, pp. 191-192, Feb. 1965
0308-821	Hoecker	Characteristics of the Radiation Polymerization Dosimeter. Health Physics Journal Vol. 8, pages 381-389, 1962
	Hoecker	Chemical Dosimetry in Biological Research. Invited paper delivered at the Tenth International Congress of Radiology, Montreal, Canada, 1962
	Bicker	M.S. Theses, University of Kansas: Relative Effectiveness of 14 MEV Neutrons and 200 KVP X-rays for Production of Lethality in Grasshopper Embryos - A Preliminary Study - 1962
	Devanney	The Study of Gelation of Triethylene Glycol Dimethacrylate Using 14 Mev Neutrons - 1963
	Hansen	Determination of the RBE of 14 Mev Neutrons Using 14 Day Old Grasshopper Embryos (<i>Chortophaga viridifasciata</i> and <i>Encoptolophus sordidus</i> - 1963)
	Metcalf	Some Factors Which Influence the Sensitivity of <u>Escherichia coli</u> B/r to Radiation - 1964
	McCluggage	The Application of the Findings of Small Group Studies to Space Exploration
0310-821	Yu	Mechanics of Blood Flow
0402-821	Burgstahler	Chemistry of <u>o-Di-t-butylbenzene</u> , <u>J. Amer. Chem. Soc.</u> , <u>86</u> , 5281 (1964)
		Synthesis and Spectral Properties of 2, 6-Dimethyl- <u>t-butylbenzene</u> (<u>Tetrahedron Letters</u> , 1625, 1965)
		Synthesis of Fichtelite and Related Derivatives of Abietane, <u>J. Org. Chem.</u> , <u>34</u> , 1562 (1969)
0404-821	Adams	Anodic Oxidation of 5, 10-dihydro-5, 10-dimethylphenzaine. <u>Z. anal. Chemie</u> , <u>224</u> , 184 (1967)

CRINC Number	PRINCIPAL INVESTIGATOR	PAPERS/EXHIBITIONS
0404-821 (continued)	Adams	<p>The Reduction of N, N-dimethyl-p-nitrosoaniline, J. Electro. Chem., <u>14</u>, 119 (1967)</p> <p>One-electron oxidation of aromatic hydrocarbons. J. Amer. Chem. Soc. <u>89</u>, 5766 (1967)</p> <p>New practical construction of platinum rotated disk electrodes. Analy. Chem. <u>39</u>, 1898 (1967)</p>
0411-821	Harmony	Pseudorigid-Rotor Behavior and Centrifugal Distortion in the Microwave Spectrum of 1, 3-Cyclohexadiene; J. Chem., Phys. <u>43</u> , 3768 (1965)
0412-821	Kitos	Utilization of 1- ¹⁴ C-glucose by Chlorella pyrenoidosa under intense illumination, by C.T. Wang, Dept. of Comparative Biochemistry and Physiology, 1965
0413-821	Mertes	M.P. Mertes and A.A. Ramsey w-Dithiolanoamino acids, J. Med. Chem., <u>12</u> , 342 (1969)
0417-821	Mesler	A Photographic Study of the Dynamics and Damage Capabilities of Bubbles Collapsing Near Solid Boundaries, N.D. Shutler and R.B. Mesler, Trans. ASME, Journal of Basic Engineering, Ser. D., <u>87</u> No. 2, June 1965, pp. 511-17. (Awarded the Robert T. Knapp Award, Fluids Engineering Division, ASME 1967)
0427-821	Bauleke	Masters Theses: An Electron Microscope Study of MICA, by Ramon A. Mayor-Gutierrez - KU Library, 1964. Electron Micrograph from work won first prize in the student division of the 1964 Ceramagraphic Show American Ceramic Society, published in August issue 1964 Bull of American Ceramic Soc.
0433-821	Akagi	Hydrogenase of Coleman's Sulfate-Reducing Bacterium Phosphoroclastic Reaction of Clostridium Nigrificans
0601-821	Akagi	Pyruvate-carbon Dioxide Exchange Reaction of Desulfovibrio. Purification of Acetokinase from Desulfovibrio Desulfuricans. The Participation of Terredoxin of Clostridium Nigrificans in Sulfate Reduction.
0603-821	Bauleke	Masters Theses: Non-Metallic Dispersions in Hot-Pressed Aluminum Powder by Babu Narain Thakur, 1965 (KU Library)
0611-821	Mertes	M.P. Mertes and A.A. Ramsey, w-Dithiolanoamino acids, J. Med. Chem., <u>12</u> , 342 (1969)
0612-821	Wright	Problems of Methodology in Hibernation Studies (brief report at American Psychology Association meeting)

CRINC Number	PRINCIPAL INVESTIGATOR	PAPERS/EXHIBITIONS
0614-821	Moore	See the following:
		Technical Report 48-7, Literature Survey on Scattering from Layered Media, by A. Leovaris (July, 1966)
		Technical Report 48-3, Scattering Theories and Radar Return, by A.K. Fung (May, 1965)
		Technical Report 48-1, Exact Solution of the Scattering of Waves from a Rough Surface, (June, 1964)
		Theory of Radar Scatter from Rough Surfaces. Bistatic and Monostatic with Application to Lunar Radar Return, <u>Journal of Geophysical Research</u> , v. 69, No. 6, pp 1063-1073, (March, 1964)
		Effects of Structure Size on Moon and Earth Radar Returns at Various Angles, <u>Journal Geophysical Research</u> , vol. 69, No. 6, pp. 1075-1081 (March, 1964),(by Fung and Moore)
		Technical Report 48-5, Scattering and Depolarization of Electromagnetic Waves by Rough Surfaces, Nov. 1965,
		Technical Report 48-6, Frequency Dependence of Waves Scattered by Rough Surfaces, (Dec., 1965)
		Fung, Moore and B.E. Parkins, Notes on Backscattering and Depolarization by Gently Undulating Surfaces, <u>Journal Geophysical Research</u> , v. 70, No. 6, pp 1559-1562 (March, 1965)
		Technical Report 48-8, Polarized and Depolarized Powers Returned from a Dielectric Rough Surface, (July, 1966)
		Scattering and Depolarization of EM Waves from a Rough Surface, <u>Proc. IEEE Letters</u> , v. 54, No. 3, pp 395-396 (March, 1966)
		The Correlation Function in Kirchhoff's Method of Solution of Scattering of Waves from Statistically Rough Surfaces, <u>Journal Geophysical Research</u> , v. 71, No. 12, pp 2939-2943 (June, 1966)
		<u>On Depolarization of Electromagnetic Backwaves/Scattered from a Rough Surface, Planetary Space Science</u> , vol. 14, pp 563-568 (July, 1966)
		Vector Scatter Theory Applied to Moon and Venus Radar Return, <u>Proc. IEEE Letters</u> , vol. 54, No. 7, pp 996-998 (July, 1966)
		Frequency Dependence and Surface Roughness, <u>Proc. IEEE Letters</u> , vol. 54, No. 10, pp. 1482-1483 (October, 1966)
		<u>Theory of Cross-Polarized Power Returned from a Random Surface, Applied Science Research</u> , vol. 18, pp 50-60 (August, 1967)
		R.K. Moore, Radar Astronomy Usage, <u>IEEE Spectrum (Correspondence)</u> , vol. 3, No. 4, pp 156-159 (April, 1966)
		B.E. Parkins and R.K. Moore, Omnidirectional Scattering of Acoustic Surfaces of Known Statistics, <u>Journal Acoustical Society of America</u> , vol. 40, No. 1, pp 170-175 (July, 1966)

CRINC Number	PRINCIPAL INVESTIGATOR	PAPERS/EXHIBITIONS
0802-821	Willems	<p>Parametric Stability of Rectangular Plates with Closely Spaced Stiffeners, Developments in Mechanics, Vol. 5, Proceedings of the 11th Midwestern Mechanics Conference, Paper No. 24, pp 387-405 (co-author R. C. Duffield)</p> <p>Parametric Resonance of Stiffened Rectangular Plates, ASME Journal Applied Mechanics, Paper 71-APM-26, 1971 (co-author R. C. Duffield)</p> <p>An Investigation of the Parametric Resonance of Rectangular Plates Reinforced with Closely Spaced Stiffeners by Nicholas Willems (co-author R.C. Duffield). Studies in Engineering Mechanics Report No. 31, Center for Research, University of Kansas, Lawrence, Kansas - August 1968.</p> <p>An Investigation of Dynamic Instability of Stiffened Rectangular Plates by Nicholas Willems (co-author R.C. Duffield). Studies in Engineering Mechanics Report No. 28, Center for Research, The University of Kansas, Lawrence, Kansas - March 1968.</p>
0807-821	Lenzen	<p>Temperature Gradients in Thick Hollowed Tori</p> <p>Polar Axisymmetric Free Oscillations of Thick Hollowed Tori</p> <p>Circumferential Axisymmetric Free Oscillations of Thick Hollowed Tori</p> <p>(Dissertation: Axisymmetric Free Oscillations of Thick Toroidal Shells) University of Kansas 1966</p>
0810-821	Kaesler	<p>Numerical Taxonomy in Invertebrate Paleontology</p> <p>Numerical Taxonomy of Selected Recent British Ostracoda</p> <p>Uses of Numerical Taxonomy in Paleontology</p>
0811-821	Willems	Bending of Skew Plates of Ariable Rigidity, ASME Journal of Applied Mechanics, June 1972, pp. 617-619 (Co-author Saad S. Mahmood)
0812-821	Kohlman	Dynamic Stability of a Tethered Parafoil (Published in AIAA Student Journal)
0815-821	Himes	Thermostability of Glycolytic Enzymes From Thermophilic Clostridia. Can.J. Microbiology., 5:461 (with N. Howell and J.M. Akagi) 1969.
1004-821	Faiman	Hyperbaric Oxygenation and Brain Norepinephrine and 5-Hydroxytryptamine: Oxygen-Pressure Interactions
1007-821	Leaders/Norton	Effect of Drugs and Confinement on Vasomotion in the Conscious Rat

PAPERS - Page Five

CRINC Number	PRINCIPAL INVESTIGATOR	PAPERS/EXHIBITIONS
1202-821	Beard	<p>The Earth's Bow Shock in an Oblique Interplanetary Field. <u>Cosmic Electrodynamics</u> <u>2</u>, 381-395, (1972)</p> <p>The Magnetic Field in the Earth's Tail. <u>Planet and Space Science</u> <u>21</u>, 528, (1973)</p> <p>Precise Calculation of the Magnetosphere. <u>Planet and Space Science</u> <u>21</u>, 485 (1973)</p> <p>Self Consistent Theory of the Magnetotail. <u>Planet and Space Science</u> <u>18</u>, 1349 (1970)</p>
1501-821	Friauf /Kevan/ Culvahouse/Zeller	<p>Optical Absorption Spectrum of Trapped Dielectrons in Alkaline Ice. <u>Solid State Communications</u> <u>6</u>, 469 (1968)</p>
1701-821	Friauf / Zeller/ Culvahouse	<p>Chemical Alterations Resulting from Proton Irradiation of the Lunar Surface. <u>Modern Geology</u> <u>1</u>, 141 (1970)</p> <p>EPR of Ag⁰ Site Conversion in Gamma-Irradiated Frozen AgNO₃ Ices. <u>Chem.Phys.Letters</u> <u>3</u>, 484 (1969)</p> <p>EPR Studies of Silver Atom Formation and Enhancement by Fluoride Ions in Gamma-Irradiated Frozen AgNO₃ Solutions. <u>J.Phys. Chem.</u> <u>74</u>, 1098 (1970)</p> <p>Paramagnetic Relaxation of Silver Ions in Gamma-Irradiated Frozen Aqueous Solutions. <u>J. Chem. Phys.</u> <u>52</u>, 4644 (1970)</p>
1707-821	Wike /Lenzen/ Wike	<p>Effects of Prolonged Low-frequency Whole-body Vibration On Rats. <u>Psychonomic Science</u>, 1972, <u>29</u>, 29-31.</p> <p>Escape Conditioning and Low-frequency Whole-body Vibration: The Effects of Frequency, Amplitude, and Controls for Noise and Octivation. <u>Psychonomic Science</u>, 1972, <u>27</u>, 161-164.</p>
1709-821	Kanet/Ketzel	<p>The Legal and Political Implications of the Development and Implementation of Remote-Sensing Devices. Mimeographed report presented to the Center for Research, Inc., November, 1971, 97 pp.</p> <p>Remote Sensing as a Challenge to Political and Administrative Organization in the United States. Presented at the annual meetings of the American Political Science Assoc., September 7-11, 1971, Chicago, Illinois.</p> <p>Earth Resources Surveying: A Policy Study. M.A. Thesis by Sandra Hartley, Dept. of Political Science, KU, 1971, 141 pp.</p> <p>The Political Problems of Remote Sensing. Presented at the Rocky Mountain Regional Meeting of the American Association of Geographers, Oct.22,1971. Colorado.</p>

<u>CRINC Number</u>	<u>PRINCIPAL INVESTIGATOR</u>	<u>PAPERS/EXHIBITIONS</u>
1801-821	Friauf/ Zeller/Culvahouse	<p>Hydrogen Defects in Proton Bombarded KCl. <u>Physics Letter</u> 38A 179 (1972)</p> <p>An ESR and ENDOR Study of the Ag⁰ Center in KCl and NaCl. <u>Physics Review</u>, in press (1974)</p> <p>EPR Studies of Multiple Ag⁰ Trapping Sites Produced in Gamma-Irradiated Frozen Silver Nitrate Ices. <u>J.Chem. Phys.</u> 55, 1327 (1971)</p>
1802-821	Zeller	<p>Chemical Reactions in Diamond Induced by Heavy Particle Bombardment</p> <p>Chemical Alterations Resulting from Proton Irradiation of the Lunar Surface</p> <p>Das Verhalten des Steinsalzgitters unter dem Einfluss des Energieverlustes und der Positiven Electrishaen Ladung Schneller Teilchen. (The Behavior of the Crystal Lattice of Rock Salt Under the Influence of Energy Loss and the Positive Electric Charge of Fast Particles).</p>
1803-821	Beard	<p>The Faud K Components of the Solar Corona. <u>Aps. J.</u> 176 497 (1972) (Also supported by NSF grant)</p> <p>Cumulative Interplanetary Dust Concentration on the Lunar Surface. <u>Modern Geology</u> 1, 301 (1970)</p>
1807-821	Schira - EXHIBITIONS: 1972	<p>3rd National Invitational Print Exhibit, University of Wisconsin - Green Bay, Green Bay, Wisconsin Purchase Award</p> <p>4th Annual National Print Exhibition, San Diego State College, San Diego, California</p> <p>Art Exhibit, 1st National Computer Symposium, Florida State University, Tallahassee, Florida</p> <p>University of Rhode Island, National Invitational Print Show, Providence, Rhode Island</p>
	1971	<p>7th Dulin National Print and Drawing Competition, Dulin Gallery of Art, Knoxville, Tennessee 2 Purchase Awards</p> <p>22nd National Exhibition of Prints, Library of Congress, Washington, D. C.</p> <p>Prints Reproduced in Mediterranean Review (Literary Quarterly)</p> <p>Lunar Exhibit, Natural History Museum, University of Kansas, Lawrence, Kansas</p> <p>Thirty Miles of Art, William Rockhill Nelson Gallery, Kansas City, Missouri</p>

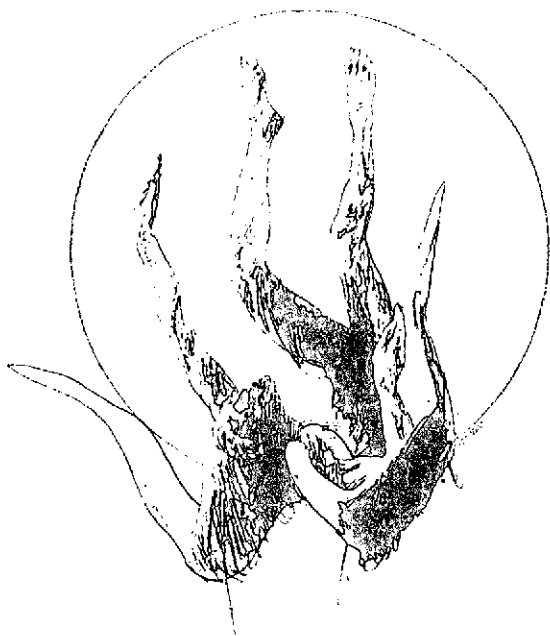
PAPERS - Page Seven

<u>CRINC Number</u>	<u>PRINCIPAL INVESTIGATOR</u>	<u>PAPERS/EXHIBITIONS</u>
1807-821 (continued)	Schira - EXHIBITIONS 1970	Faculty Exhibit, Broadview Community Church, Colorado Springs, Colorado Art for Collectors, Henry Gallery, University of Washington, Seattle, Washington New Dimensions in Media, William Rockhill Nelson Gallery, Kansas City, Missouri
1808-821	Knight/Harnapp	Remote Sensing of Tropical Agricultural Systems. Center for Research, Inc., University of Kansas, Lawrence, Kansas, 1971, 141 pp. Remote Sensing of Tropical Agricultural Systems, 7th International Symposium on Remote Sensing of Environment, pp. 409-433
1809-821	Kanet/Ketzel	(See 1709-821)
2003-821	Zeller	(See 1802-821)
2004-821	Schira - EXHIBITIONS	(See 1807-821)
2006-821	Lenzen	(See 1707-821)
2008-821	Bearse	Technique for Determination of Heavy Element Impurities in Targets, Nucl. Inst. & Methods, <u>97</u> , 607 (1971)
2202-821	Schira - EXHIBITIONS	(See 1807)
2204-821	Laird	New Dimensions in Scientific Research, Report to the Center for Research, Inc., University of Kansas, Fall of 1973, 55 pp.

The list of publications and exhibitions provided is complete as determined from project records. Some investigators did not provide a complete listing of publications or student papers directed; therefore, the listing does not include all such results from the grant.

APPENDIX 4

THE UNIVERSITY OF KANSAS SPACE TECHNOLOGY CENTER



THE UNIVERSITY OF KANSAS SPACE TECHNOLOGY CENTER

Nichols Hall

"Provided by the National Aeronautics and Space Administration and the State of Kansas for the enrichment of the University's interdisciplinary space-related studies."

WELCOME TO THE UNIVERSITY OF KANSAS SPACE TECHNOLOGY CENTER

We are pleased to welcome you to this fine facility provided for the faculty and students of the University of Kansas and dedicated to learning, research, and service for the benefit of the people of Kansas and the nation.

This Center houses a broad range of multidisciplinary research efforts in the areas of earth resources and the environment; solutions applicable to problems found in the State of Kansas are of particular importance.

Research such as that conducted in the STC is important for its direct results--new knowledge, ideas, concepts, hardware, and software. It is also of importance because new ideas can result in economic value for the state and region as shown by the several new businesses operating in the Lawrence area as outgrowths of research experience on projects now housed in the Center.

Perhaps most important is the relationship of research to the instructional mission of the

University. A high-quality university education requires professors who are knowledgeable about the latest developments in their specialties. Many advanced degrees prepare students for careers in research. Frequently their training, best guided by a professor active in research, is part of larger institutional projects such as those underway here in Nichols Hall. As a side benefit, many such students obtain financial support from research funds. The pursuit of new knowledge through research provides a continual revitalizing input to a teacher's knowledge and enthusiasm. A researcher's fresh knowledge, personal involvement, and desire to find answers to pressing problems customarily make him or her a more effective teacher.

The University of Kansas is proud of its new Space Technology Center and the opportunities it offers in education, research, and service to the State and region. We hope you find your visit to the Center informative and enjoyable.

THE UNIVERSITY OF KANSAS SPACE TECHNOLOGY CENTER

The KU Space Technology Center was designed to establish a physical environment which would be conducive to cooperation between disciplines.

The building was funded primarily by the National Aeronautics and Space Administration in response to a proposal submitted by the KU Space Science and Technology Committee in 1965-66. The Space Committee, composed of men from different fields of study such as engineering, physical sciences, and the life sciences, envisioned a building for interdisciplinary research--that research which successfully bridges the chasm between one field of research and another.

The building is dedicated to research for the benefit of society. The multidisciplinary purpose of the building is working with mission-oriented research ("people problems") as well as theoretical research.

Laboratories housed in the building have separate entities although they are meshed in the overall research purpose of the building. In this way the expertise of varied fields is combined to seek solutions to our environmental and societal problems.

Principal funding for the Center consisted of 1.8 million dollars from the National Aeronautics and Space Administration and \$354,000 from the State of Kansas. The University has invested about \$316,000 for furnishings, equipment, and special building features. In addition, considerable state and federal project funds and excess federal equipment has been obtained for use of various research projects in the Center.

The 70,000 square foot building now houses about 200 faculty members and students from most of the major University departments including business, engineering, and the social, biological and physical sciences. There are 35 laboratories, 75 offices, conference-seminar rooms, a reading room, computer terminal, auditorium, and support services, including a photography laboratory, drafting facilities, and a shop area.

It is now almost universally recognized that the problems man faces demands that they be solved

by multidisciplinary teams of investigators so that the expertise of many fields can be brought to bear. Nichols Hall provides the setting for this type of effort at KU.

MAJOR RESEARCH ACTIVITIES

The Space Technology Center houses a broad research base including a wide range of multidisciplinary efforts in the areas of earth resources and environment. Investigations are directed toward solving "people oriented" problems relating to earth resources and the environment, especially seeking solutions applicable to problems found in the State of Kansas.

NASA continues to support the recognized expertise at the University of Kansas as shown by several large investigations now underway which are sponsored by NASA.

Recent research focused on the NASA funding of a balanced program of multidisciplinary research, the Kansas Environmental Resource Study (KERS) Program which uses data generated from the Earth Resources Technology Satellite (ERTS) and the SKYLAB manned space station.

The KERS program, designed to serve as a model for the use of satellite data by the Great Plains states, is coordinated by The University of Kansas Center for Research, Inc. Participants include KU, the Agricultural Experiment Station of Kansas State University, the Kansas Geological Survey, and other state agencies. Multidisciplinary groups of investigators from the cooperating institutions work in teams to apply data in specific agricultural, geological, geographical, and hydrological studies of Kansas and the Great Plains.

Under the KERS program, several research investigations may have significant value for the future. One such project involves the estimation of wheat crop yields using the ERTS imagery returned from the satellite. Research findings prove that it is feasible to estimate such yields using space imagery.

The KU Remote Sensing Laboratory (RSL), directed by Dr. F. T. Ulaby, is a major research unit in the Space Technology Center.

The personnel in this laboratory are recognized internationally for their expertise in the field of remote sensing. The RSL personnel are engaged in remotely determining conditions on the earth by using radar, cameras, and other instruments carried on aircraft and spacecraft. This interdisciplinary group of faculty and students includes those whose specialties are the instruments themselves, persons who specialize in understanding why the instrument "sees" what it does, data processing specialists who try to make instrument outputs more useful, and members of the user community such as geologists and geographers for whom the remote sensor is a tool. Representing the different disciplines coordinated in this research work are Drs. R. K. Moore, L. F. Dellwig, A. K. Fung, R. M. Haralick, G. L. Kelly, A. K. Biggs, J. C. Holtzman, W. E. Hogan, II, D. I. Rummer, H. L. Yarger, and E. J. Zeller.

Studies in this large laboratory complex are varied and the RSL has conducted earth observations studies ranging from a Kansas agricultural atlas to world-wide ocean wind measurements. Support for the Laboratory's work has been provided by several NASA centers, the Department of Defense, and other governmental agencies.

The Flight Research Laboratory conducts an overall research program directed toward the advancement of aviation. Directed by Drs. D. L. Kohlman and Jan Roskam of Aerospace Engineering, research is underway toward improving the safety and operational economy of aircraft in the areas of aerodynamics, design, flight controls, propulsion, structures, aircraft operations and flight testing. Support for this major laboratory has come from the aircraft industry and NASA centers in Virginia and California.

Under the direction of Dr. Joe Eagleman, the Atmospheric Science Laboratory conducts research on the weather and various conditions relating to it. Research investigations utilize equipment for receiving photographs directly from satellites, a tornado detecting instrument in the experimental stage, atmospheric pollution instruments, and meteorological equipment.

The Satellite Applications Program, sponsored by NASA Headquarters, is for research to help

those local, state, and regional agencies involved with resource management and environmental quality use the data gathered by satellite remote sensing. The project involves seminars and workshops to which representatives of various agencies are invited. These meetings are designed to foster communication between the KU investigators and the user agencies so that maximum use of satellite derived data can be made. Professor B. G. Barr is Project Director of this work which involves faculty and students from many disciplines. He is assisted by R. L. Walters, Project Coordinator.

Under this research program, cooperative projects have been undertaken between many state agencies and KU Applications personnel resulting in information which has, for example, contributed to decisions on selection of a route for a scenic parkway, open land use policy development, urban development policy, a major reservoir project, control tactics and damage assessment during flooding conditions on the Kansas and Missouri rivers, and others.

The Business and Engineering Technical Applications (BETA) group supplies technical information to industry in Kansas and surrounding states. KU students conduct technical information searches relating to a specific problem of interest to the contracting business. BETA has recently conducted searches for industries in developing countries through the United Nations Industrial Development Organization in Vienna, Austria.

The Spatial Distribution Computer Laboratory, supported primarily by the National Science Foundation and directed by Dr. Robert E. Nunley, a geographer, is devoted to the simulation of two- and three-dimensional processes. Although designed primarily for geographic studies of urban sprawl, transportation systems, and regional development, the system is being developed for work in remote sensing, pattern recognition, petroleum and ground water engineering, architecture, and geology.

Research in the Radiation Physics Laboratory, directed by Dr. Ed Zeller of the Geology Department, is primarily concerned with the interaction of radiation with matter. A continuing program involving the effects of high energy radiation on minerals and interplanetary dust is in progress. The laboratory has participated in intensive investigations of problems related to nuclear waste disposal.

As a result of earlier work on radiation chemistry of interplanetary dust, the laboratory was given a contract by NASA to evaluate the effects of high altitude atmospheric dust on long term climatic changes. The potential use of lasers mounted in spacecraft to measure the transparency of the earth's atmosphere to incoming solar radiation is a major part of this program. The research is designed to provide a partial answer to the practical problem of whether or not human pollution of the atmosphere is capable of altering the world's climate. In addition, the laboratory is undertaking a program to aid in the evaluation of the Mariner 9 pictures of Mars.

HISTORY OF SPACE RESEARCH AT THE UNIVERSITY OF KANSAS

The University of Kansas submitted its first proposal to the National Aeronautics and Space Administration for research support through a sustaining grant from the Office of University Affairs in 1961. A grant of \$100,000 was made to the University in July 1962 to support space research in disciplines throughout the University. In a span of five years, from 1961-1965, space research and training programs at KU grew to approximately \$800,000 annually. This growth convinced the University and NASA that the nation's interest would be served by building an interdisciplinary space research facility on the campus of the University.

Two programs initiated by the interdisciplinary grant, the Remote Sensing Laboratory and the Business and Engineering Technical Applications program, had a significant part in the growth of the NASA-funded research effort and showed the potential for long-range contributions in research, development and applications.

KU's involvement in space technology led to the development of a new academic program. The Doctor of Engineering program, under the direction of Dr. Kenneth H. Lenzen, places engineering graduate students participating in the program at NASA Centers throughout the U.S. to conduct research in pertinent space-related areas on which the doctoral thesis is then based. This cooperative effort has placed KU at the forefront of engineering graduate education.

The Space Technology Center provides a focus for research involving faculty and students from departments throughout the campus permitting exploration of new directions in space and multidisciplinary research.

NICHOLS & EVANS HONORED

Nichols Hall was named in honor of Chancellor Emeritus Raymond Nichols during commencement ceremonies in the spring of 1973. The large auditorium on the first floor of Nichols Hall is named in honor of Ron Evans, Kansas astronaut. Evans presented to KU a plaque including a KU flag that orbited the moon during Evans' Apollo XVII mission. The plaque is on display in the Ron Evans Apollo XVII auditorium.

STC FILM AVAILABLE

A 30-minute film with sound and color is available on the KU Space Technology Center for showings to interested groups. The film gives a brief overview of several of the different research activities underway. Contact Center personnel if you are interested in a film showing; there is no rental charge.

ON THE FRONT . . .

Icarus, son of Daedalus, was the character in Greek mythology who flew too near the sun on man-made wings and fell to his death in the sea. The wings which were adhered by wax melted in the heat of the sun causing the wings to collapse and Icarus' plunge to death.

Icarus is symbolic of man's quest for knowledge: a willingness to venture into the unknown even though such pursuits may be hazardous.

Created in natural bronze by a recognized contemporary American sculptor, Charles Umlauf, the sculpture of Icarus is nearly 11 feet tall and stands on a black granite base. A gift of the Phillips Petroleum Company to KU, the sculpture is located in the court of the Space Technology Center.

CRINC LABORATORIES

Chemical Engineering Low Temperature Laboratory

Remote Sensing Laboratory

Flight Research Laboratory

Chemical Engineering Heat Transfer Laboratory

Nuclear Engineering Laboratory

Environmental Health Engineering Laboratory

Information Processing Laboratory

Water Resources Institute

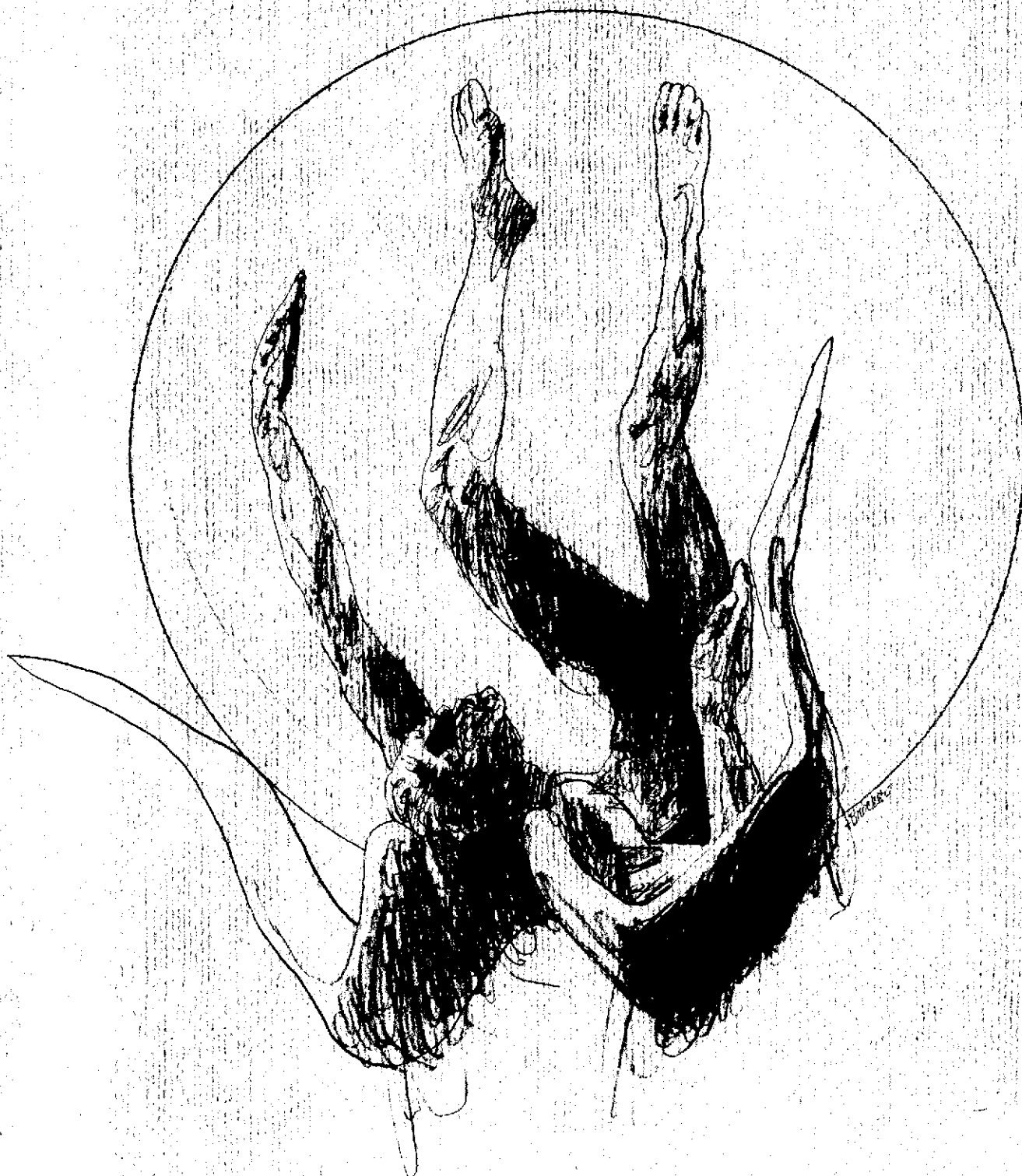
Technical Transfer Laboratory

Air Pollution Laboratory

Satellite Applications Laboratory

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

RESEARCH



THE UNIVERSITY OF KANSAS
CENTER FOR RESEARCH, INC.

RESEARCH VOLUME V

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This volume is the fifth in a continuing series of publications describing ongoing research investigations as well as recently completed projects in the engineering and interdisciplinary engineering-related areas at The University of Kansas.

Direct inquiries concerning the publication or any of the research described to The University of Kansas Center for Research, Inc., 2385 Irving Hill Road, Campus West, Lawrence, Kansas 66044.

PATRICIA NICHOLAS, *Editor*
Spring 1972



On the cover:

Icarus, son of Daedalus, was the character in Greek mythology who flew too near the sun on man-made wings and fell to his death in the sea. The wings were adhered by glue which was melted by the heat of the sun causing the wings to collapse and Icarus' plunge to death.

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Created in natural bronze by a recognized contemporary American sculptor, Charles Umlauf, the sculpture of Icarus is nearly 11 feet tall and stands on a black granite base. A gift of the Phillips Petroleum Company to KU, the sculpture is located south of the new Space Technology Laboratories.

Multidisciplinary Research at The University of Kansas

William P. Smith, Dean, School of Engineering
Director, Center for Research, Inc.

Every day the news media reports another "battle" between the environment on one side and technology on the other. One could gather from many of these items that these two concepts are completely incompatible and that eventually one or the other must prevail and no middle ground is possible. As is so often the case, this problem is not one which can be categorized as black or white, yes or no, but rather is one which is in the "grey" or "maybe" category. The complicating factor is man himself—both in numbers of population and individual standards of living. If we are prepared to accept a reduction of either or both of these, then our environmental situation would be easily improved. The real problem is to find a reasonable compromise. Few of us, for instance, would be willing to solve our environmental problems in America by returning to the pre-Columbian population of one million or so inhabitants. Also not

many of us would be willing to accept a reduction in our standard of living.

Despite a wide-spread feeling to the contrary, the technical solutions to many of these problems are already known and do not require a major technological breakthrough. The major stumbling blocks to an improved environment are economic, political, legal and psychological. However, each of these relates to the others as well as to technology. If our research is to have a meaningful impact upon the solution of society's problems, it must involve a wide spectrum of human knowledge and must not become compartmentalized in a parochial and narrow discipline. The activities of the Center for Research, Inc., have been increasingly oriented toward the multidisciplinary approach to include human and environmental as well as technical factors in the problem and the solution. I am sure this trend will continue.

The University of Kansas Center for Research, Inc.

B. G. Barr, Executive Director

The Center for Research, Inc., continues to fulfill its purpose of promoting scientific and educational advancement at The University of Kansas by encouraging and supporting fundamental and applied research. Since the Center for Research operations began just over nine years ago, support for research projects and facilities has totaled \$12.5 million, and the annual research effort at CRINC is now over \$1.3 million.

The multidisciplinary research base has extended to cover many different facets of engineering, science, and the humanities. Much of this research is in earth observation studies and the volume of activity is expected to increase with the addition of the recently completed Space Technology Laboratories. This \$2.5 million multidisciplinary research building, partially funded by a National Aeronautics and Space Administration grant, is the largest of its kind in the Midwest and houses 70,000 sq. feet including 30 laboratories and 80 offices in addition to conference rooms and a 96-seat seminar room designed for multilingual and closed circuit television presentations.

NASA has taken a special interest in the innovations and concepts employed in this building created for multidisciplinary research. A hearing held in Washington on April 6, 1970, before the Committee on Aeronautical and Space Sciences, U.S. Senate, Ninety-first Congress, recognized the unique approach being developed in the building. The PROCEEDINGS of this hearing read: "This building represents a new concept in providing a multidisciplinary environment for the conduct of space-related science and engineering work."

Dealing effectively with man's interaction with his physical environment is one of our most pressing problems, and the complexity of such problems demands that they be solved by multidisciplinary teams of investigators so that the expertise of many fields can be combined. This new building provides the facilities for uniting the capabilities of both scientists and engineers to deal with problems

of earth resources and the environment. Disciplines housed in the Space Technology Laboratories contributing to solutions in these fields include engineering, chemistry, geology, social sciences, humanities, business, physics, art, geography, microbiology, and botany. Faculty and students (both graduate and undergraduate) from these departments and schools will be working and studying as teams on projects in many of these areas.

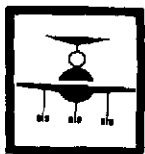
An important piece of equipment recently acquired to aid these researchers is a Beechcraft Model 18 twin-engine aircraft which will augment the Center's Cessna craft. The craft will be used as a flying research platform to test instrumentation and perform experiments in conjunction with earth observation and air pollution research. It will be equipped with a radar scatterometer, four Hassleblad vertical-looking cameras, and a metric mapping camera.

In addition to the Space Technology Laboratories, other facilities for conducting research are located in the various engineering and other University departments. The Center for Research building itself houses 13,000 sq. feet of administration and research offices.

The Center staff provides support service for the participating investigators by furnishing administrative functions including proposal preparation, budgetary and accounting services, publication services, etc.

Research through CRINC can be supported by outside sponsors in a variety of ways including cooperative agreements, research grants, and special contracts. The increasing research activity of the investigators of the University of Kansas provides opportunities for graduate assistantships for engineering and science majors interested in pursuing advanced degrees. The research project summaries in this publication indicate the areas in which these opportunities exist.

CRINC policy provides full cooperation with regional industry for research and development. Area industries and businesses are invited to visit or contact the Center for more information about facilities, interests, and capabilities.



AEROSPACE ENGINEERING

David L. Kohlman, Chairman

The Aerospace Engineering Department has a primary interest in the technology of winged vehicles, with a special emphasis on light and general aviation aircraft. A significant level of research activity is being conducted in our laboratories, and faculty are serving as consultants to Beech, Bell Helicopter, Boeing, Cessna, Lear Jet, and the FAA.

A major research facility, a fixed-base visual and instrument flight simulator, is now in operation. This greatly enhances our ability to solve problems involving pilot response, cockpit and control system design, handling qualities, and stability augmentation.

Other facilities for research include a subsonic wind tunnel with 6-component balance and automated data readout, a structural test laboratory, instrumentation laboratory, and a Cessna 172 and Cessna Cardinal for flight test work.

Research is now being conducted in the areas of light airplane design, gust alleviation, separate surface stability augmentation, aerodynamic analysis of flexible wings, high lift systems, and direct lift control.

Graduate students continue to play a major role in this research activity with undergraduates often supplying excellent assistance. The recent approval of a cooperative Ph.D. program between the Aerospace Engineering Department at K.U. and the Aeronautical Engineering Department at Wichita State University should lead to a major increase in graduate students and aerospace research at K.U.

AEROSPACE VEHICLE STRUCTURES

Howard W. Smith
University of Kansas

The primary purpose of the structures research work is to supplement the students' classroom curriculum. A secondary objective

is the building of a fundamental capability to perform aerospace vehicle structural design and analysis. Since August 1970, twelve students were involved in research projects; ten of the students were undergraduates. New computer programs, operable on the GE/Honeywell 635, were developed in the following areas of study:

1. Wing Bending/Torsion Flutter
2. Wing Stress and Deflection Analysis
3. Wing Airloads, Shears, and Moments
4. Matrix Displacement Structural Analysis
5. Hardy Cross Multispan Beam Analysis
6. Class I Preliminary Structural Design

A small group of students worked on the design and analysis of a modified wing for a Cessna Cardinal. Topics studied were the main spar bending material, in-spar ribs, Kruger flaps, wing-to-fuselage fittings and attach bolts, wing torsional stiffness and the overall loads criteria.

Two new topics, started in May 1971, are (i) Investigation of "POGO," and (ii) A Compilation of Aerospace Engineering Computing Programs into a Permfile.

INVESTIGATION OF THE AERODYNAMICS AND MINIMUM INDUCED-DRAG CONFIGURATIONS OF JET-FLAPPED WINGS WITH PARTIAL SPAN BLOWING

C. T. Lan
University of Kansas

An analytical lifting surface theory for a wing with either internal or external jet-augmented flaps is being developed. The analytical method can be used to generate the design aerodynamic data for a jet-flapped wing with partial span blowing and to find the minimum induced drag configuration. The finite element method is being used.

IMPROVED CONTROL METHODS FOR LIGHT AND GENERAL AVIATION AIRCRAFT

**David L. Kohlman, Jan Roskam, Howard Smith,
Don Collins, and Carl Brainerd
NASA-Langley Research Center**

Through theoretical parametric studies, wind tunnel testing, and flight simulator investigation, major modifications have been proposed for a typical light airplane. To improve cruise speed, handling qualities, gust response, and safety during final approach and landing the following modifications will be made to the test airplane, a Cessna Cardinal:

- Significant decrease in wing area
- Increased wing aspect ratio
- Improved high lift system incorporating Fowler and Kruger flaps
- Lateral control with spoilers
- Direct lift control using spoilers during final approach and landing

An existing Cardinal has been fully instrumented to obtain base flight test data on the present configuration. During the winter of 1971-72, the modifications will be made to the airplane and an extensive flight test program has been planned to determine the resulting performance and flight characteristics of the new configuration.



Modification adjustments being made to Cardinal model prior to wind tunnel testing.

A parallel program of research is being carried out using the flight simulator to determine the most favorable method of pilot control input to the direct lift control system. The method which offers the most natural and precise control of flight path during final approach and landing will be incorporated in the modified Cardinal.

CONTINUED INVESTIGATION OF α - AND q -STABILITY DERIVATIVES OF ELASTIC AIRPLANES

**J. Roskam, C. Lan, H. Smith, S. Mehrotra,
S. Kaul, and G. Gibson
NASA-Langley Research Center**

The objective of this research is to develop finite-element methods for estimating the effect of structural deformations on stability and control characteristics of advanced aircraft configurations.

INVESTIGATION OF SEPARATE SURFACE STABILITY AUGMENTATION (SSSA) SYSTEMS FOR LIGHT AND V/STOL AIRPLANES

**J. Roskam, D. L. Kohlman, R. Klein,
and S. Henry
NASA-Flight Research Center**

The purpose of this research program is to improve handling characteristics of light and STOL airplanes by providing separate control surfaces for autopilots and stability augmentation systems. The primary advantage of such a system is the elimination of force and deflection feedback to the pilot through the primary control system. It also offers reductions to the weight and complexity of such systems, while improving the capability to tailor the control response of the airplane to provide the most favorable handling qualities.

This program will investigate this concept through theoretical analysis, wind tunnel tests, flight simulator studies, and finally, the implementation of a system in an existing airplane.

AN INVESTIGATION OF A VORTEX AUGMENTED WING

Jan Roskam and Mark Gleason
University of Kansas Research Grant

This study investigates the feasibility of creating a stable two vortex flow system around lifting surfaces. When feasible, such a system would allow airplanes to land in very short distances with minimal noise.

Results so far have been inconclusive. It has been established, however, that stable vortices can be generated in the manner proposed.

AN ANALYTICAL METHOD OF COMPUTING LATERAL-DIRECTIONAL STABILITY DERIVATIVES OF WING-BODY COMBINATIONS IN SUBSONIC AND SUPERSONIC FLOWS

C. T. Lan
University of Kansas

An analytical method of including the wing-body interference with arbitrary body shapes is being investigated in this study. The method is to be applied to the computation of the lateral-directional stability derivatives of any wing-body combination in subsonic and supersonic flows. The distribution of vortex-multiplets on the body axis and that of pressure vortices on the wing chord plane are found with the finite element method.

AN INVESTIGATION OF AIRCRAFT TRAFFIC OPERATIONS AND PROCEDURES IN A HIGH DENSITY TERMINAL AREA

Kenneth H. Lenzen and Charles E. Knox
NASA-Langley

During the past five years the need for improvement of the United States' Air Traffic Control (ATC) system has been very dramatically illustrated by air carrier delays in arrival and departure times, mass cancellation of scheduled flights, and by the air traffic controllers' "fly by the book" or "slow down" tactics. The ATC systems' inadequacy was

caused by the large growth of passenger-miles in intercity travel on the airlines and rapid increase of numbers in general aviation and corporate aircraft, coupled with little research and development in the area of ATC.

The present ATC system could be divided into two parts: enroute operations and terminal area operations. Enroute operations include all activities conducted by an aircraft while it is not under approach control or departure control of any airport. Except for certain routes and preferred altitudes in some sections of the country, the enroute portion of the ATC system does not appear to be saturated at this time.

Terminal area operations include all aircraft arrivals and departures, by both Visual Flight Rules (VFR) and Instrument Flight Rules (IFR) flights, in the airport control zone which is defined by the Airman's Information Manual as "Airspace extending upward from the surface of the earth which may include one or more airports and is normally a circular area of five statute miles in radius with extensions where necessary to include instrument approach and departure paths."

Terminal area operations and, in particular, congestion of the actual runway or runways of an airport is the greatest bottleneck of the present ATC system. Occasionally, terminal area operations have become such a major point of air traffic congestion that the ATC enroute operations have been undesirably affected and caused reduced enroute operational efficiency.

A THEORETICAL INVESTIGATION OF THE AERODYNAMICS OF LOW ASPECT-RATIO WINGS WITH LEADING EDGE SEPARATION

C. T. Lan
University of Kansas

A theoretical method is being investigated for predicting the pressure distribution, lift and pitching moment coefficients of low aspect-ratio wings with the separated leading edge vortex system taken into account. No assumptions of slenderness and conical flow are being made.



CHEMICAL AND PETROLEUM ENGINEERING

Don W. Green, Chairman

The research in the Department encompasses a broad spectrum of interests, ranging from very basic research on the phenomenon of boiling to applied studies aimed at the solution of environmental problems. The entire effort is strongly integrated with the program of graduate and undergraduate education. Most projects involve M.S., Ph.D. or Dr. of Engineering degree candidates with the work leading to graduate theses. In addition, undergraduates often take part as typified by the Department's continued involvement in the NSF Undergraduate Research Participation Program.

Funding for the research effort has come from several sources. The principal ones are the National Science Foundation, Office of Water Resources Research, industry and the State of Kansas. Projects relating to environmental concerns have been on the increase as it has become ever clearer that engineers must accelerate their attack on many pollution control and energy conservation problems. The Department is also doing more interdisciplinary research involving, for example, the Civil and Electrical Engineering Departments and the Kansas and U.S. Geological Surveys. Departmental projects are also described in the Water Resources Laboratory section.

The primary research areas are the following:

Low Temperature Thermodynamic and Transport Properties:

The cryogenics laboratory is equipped with a helium cryostat, liquid nitrogen generator and equipment for the measurement of thermodynamic and transport properties of pure and multi-component systems at low temperatures and/or high pressures. Thermodynamic studies include phase behavior, measurement of volumetric properties, and calorimetric studies. Transport investigations include studies on viscosity, thermal conductivity, and diffusivity.

Heat Transfer with Change of Phase:

Heat transfer during boiling is being studied using high speed motion-picture photography (up to 35,000 frames/second) and sophisticated electronic equipment to sense and record temperature behavior in the region of bubble formation. The research has been extended to study cavitation effects and the reaction (often very violent) of molten metals with water.

Process Dynamics and Control:

The application of mathematical modeling and optimal and sub-optimal control to chemical processes is being investigated. Projects include predictive control of processes with stochastic inputs, implementation of optimal control subject to state variable constraints and systematic improvement of mathematical models of chemical processes.

Chemical Reaction Kinetics and Process Design:

Emphasis has been on the kinetics of reactions in heterogeneous systems. A current study involves the kinetics and mass transport at the interface between reacting immiscible liquids. Studies are also being made of reactions between gases and solids and reactions catalyzed by solid materials. Methods of removal of sulfur contaminants utilizing packed-bed processes are being examined.

Transport Processes in Porous Media:

Several projects relating to hydrocarbon reservoirs and to ground-water resources are underway. A physical model of a gas reservoir has been developed in which the time scale can be compressed several orders of magnitude. This makes possible short-term laboratory investigations of phenomena that would otherwise have to be analyzed using field data taken over periods of several years. In another project, a new method of characterizing porous media utilizing methods of statistical communication theory has been tested. At-

tempts are now being made to relate the characterization to flow phenomena in the porous media. Other studies include experimental investigations of the adsorption and dispersion of pollutants as they flow through porous media such as a soil or a fresh-water aquifer.

Analysis of Systems Using Computer Modeling:

For several years there has been a major emphasis on mathematical modeling of hydrocarbon reservoir production processes. Multi-dimensional and multi-phase flow models have been developed. Recently, optimization models have been applied in conjunction with the models of the fluid-flow processes. Two new projects have been directed at environmental problems. In one, the behavior of a chemically reacting pollutant that has been discharged from a plant stack is being modeled. In the second, a method of dissipating waste heat from a power plant by injecting the hot water into a ground-water system is being analyzed. Wherever feasible, the computer models are being checked against laboratory and/or field data.

EXPERIMENTAL AND MATHEMATICAL MODELING OF TRANSIENT GAS FLOW IN POROUS MEDIA

G. W. Swift, V. Hernandez, and D. Stephenson
University of Kansas Research Grant

An experimental model has been constructed which will be operated to simulate the transient production of gas from a finite reservoir containing a homogeneous porous medium. The model is a scale replica of a one-well reservoir, with a producing well at the center of a right cylinder of porous material confined within a pressure vessel, and with ten to twenty observation wells located at strategic points away from the producing well. Particular interest will be given to the study of flow from tight reservoirs where the movement of the radius of drainage out into the reservoir is an appreciable part of the total production time. Also, the study of the non-Darcy effect on transient behavior will be investigated. Properly scaling the permeability and size of the model will reduce the time required to produce at a given rate (or at a given well bore pressure) from dis-

covery to abandonment by a factor of approximately 10^5 ; thus, the model production history will be obtained in one to two hours whereas twenty years would be required to obtain the production history of a comparable commercial well. Pressure transducers at the production and observation wells and coupling of the output of these transducers to an analog-to-digital conversion system provide a printed tape record of pressure gradient propagation as a function of time during each of the two controlling modes of transient production. The tape record will be used to form input for a computer program which is to be used to compare the experimental results with existing theory. Differences between experiment and theory will be used to develop better theoretical methods to explain the flow of gas through porous media.

The porous medium found to be most suitable for the model is a portland cement-sand mortar, manufactured in the laboratory under closely controlled conditions. By using appropriate water/cement and sand/cement ratios for the mortar mix and by properly controlling the curing and drying conditions, mortars are prepared which have properly-scaled permeabilities (0.01-0.1 millidarcies) and porosities of 10-15%.

In connection with this project, a study of the steady flow of highly non-ideal gases through a porous medium has also been initiated.

THERMODYNAMIC AND TRANSPORT PROPERTIES OF DENSE FLUID SYSTEMS AT LOW TEMPERATURES AND/OR HIGH PRESSURES

F. Kurata, G. W. Swift, and D. R. Laurance

The research encompasses the determination and correlation of (1) phase equilibrium data (vapor-liquid, vapor-liquid-solid, liquid-liquid, etc.), (2) pressure-volume-temperature data precise enough to allow subsequent computation of derived thermodynamic properties such as enthalpy, and (3) viscosity data for systems composed of methane, ethane, propane, and nitrogen. A systematic study will be made of the binary, ternary, and multi-component combinations of these molecular species. Studies will be conducted at tem-

peratures from the triple-point locus to 373°K and at pressures to 800 atm.

Presently, work is in progress on phase equilibria in mixed (paraffin, olefin, diolefin) C₄ hydrocarbon systems, and on the viscosities and densities of light hydrocarbon systems. Apparatus used in this project can be operated at temperatures from 50-400°K and at pressures to 12,000 psia.

PREDICTING BUBBLE SHAPES

Russell Mesler and William Manning
University of Kansas

Liquid inertia significantly affects bubble shape while a bubble is growing during nucleate boiling. The exact effect has been difficult to assess because doing so requires the solution of the governing fluid mechanics equations. Only recently has it become feasible to solve these equations as applied to bubble growth using a high speed computer and a technique developed at Los Alamos known as the Marker and Cell method.

PREDICTION OF RESERVOIR FLUID FLOW PROPERTIES AND THEIR SPATIAL VARIATION

Floyd W. Preston, John C. Davis, Don W. Green, Curtis Conley, and M. Y. Joshi
American Petroleum Institute and
Kansas Geological Survey

An attempt is being made to develop techniques of numerically predicting porosity, permeability, capillary pressure and other porous media properties from optically digitized photomicrographs of reservoir rock samples. Statistical procedures based upon Fourier spectral analysis form the basis for the methods being applied. Earlier work has shown that the power spectrum from a rock sample does serve to "characterize" the rock and may therefore be correlatable with the rock physical properties.

The results of the spectral analysis are being applied in conjunction with mathematical reservoir simulators. The spectral analysis is being used to improve the definition of allow-

able variability of reservoir parameters used as input data in the models.

Another project objective is to create a theoretical mathematical model of a given porous medium based on Fourier Analysis methods. The mathematical model being sought would have the same statistical properties as the original medium.

TRANSPORT OF AGRICULTURAL CHEMICALS THROUGH POROUS MEDIA

G. Paul Willhite and E. N. Odimgbe
University of Kansas

The transport of fluometuron through a packed bed of glass beads was investigated by analyzing the concentration profiles of the effluent from the bed following step changes in the input concentration. Fluometuron was chosen for this study because its adsorption isotherm was found to have a region where dispersion could be studied independently of adsorption. Dispersion coefficients determined from experiments in this region were used in a mathematical model to simulate effluent concentrations from the packed column. Dispersion and adsorption were the principle transport mechanisms.

PREDICTION OF CHEMICAL POLLUTANT CONCENTRATION PROFILES RESULTING FROM EMERGENCY RELEASE OF A CHEMICALLY REACTING SYSTEM

Harold F. Rosson and Pradeep Beri
University of Kansas Research Grant

The manufacture of most chemical products and intermediates is accomplished within a containing vessel or chemical reactor. Frequently, the reacting system may be composed of hazardous or toxic substances and may be at high pressure and temperature. In such cases it may be necessary to provide for emergency release of the contents of the vessel should a reactive excursion be experienced. A common method of release is to vent the material out a vertical stack into the atmosphere.

A vast amount of meteorological research has been done to predict concentrations of non-reacting and radioactive material released either in a puff or a plume, but no work has been done to include the effect of coincident chemical reaction. The research objective is to develop a method to include this effect.

The general equations of continuity, momentum, and energy are being used to model the system and a computer program has been written to apply the model in two dimensions to a nonreacting system. If and when all the "bugs" are removed, the model will be extended to a reacting chemical system.

OPTIMIZATION OF DEVELOPMENT OF UNDERGROUND RESERVOIRS THROUGH APPLICATION OF MATHEMATICAL MODELING

Don W. Green and Gary W. Rosenwald
University of Kansas

Techniques are being sought for optimizing the development of hydrocarbon and ground-water reservoirs. The optimization techniques will be used in conjunction with previously developed mathematical models (digital computer models) which are analogues of reservoir fluid flow processes. The mathematical models basically consist of the partial differential equations describing flow in a multi-well reservoir and numerical algorithms for the equation solutions. For any selected set of reservoir conditions (geometry, flow rates, etc.) and well configuration, the models can be used to calculate reservoir flow behavior. However, the models cannot, except by trial and error procedure, be used to determine optimum ways of development or operation, as for example, an optimum well configuration or an optimum well production schedule.

The aim of this work is to develop optimization procedures that could be applied with the mathematical models to locate optima of the type desired. Generally, the problem is one of searching for formal techniques of optimization that can be used in conjunction with large-scale digital computer models that describe complex physical systems, particularly petroleum or ground-water reservoir systems.

MISCIBLE DISPLACEMENT PROCESSES IN POROUS MEDIA

Don W. Green, Ronald L. Cox, Surjit S. Chhatwal, and Bharat H. Gandhi
University of Kansas

Liquid-liquid miscible displacement processes at low rates of flow in porous media are being studied in the laboratory and through the development of mathematical models. In such systems, the liquid-liquid interface is not sharp, but rather a transition zone develops as the result of dispersion. Effects such as gravity override or viscous fingering can be present causing a spread of this transition zone. Heterogeneities in the porous media will also affect the displacement.

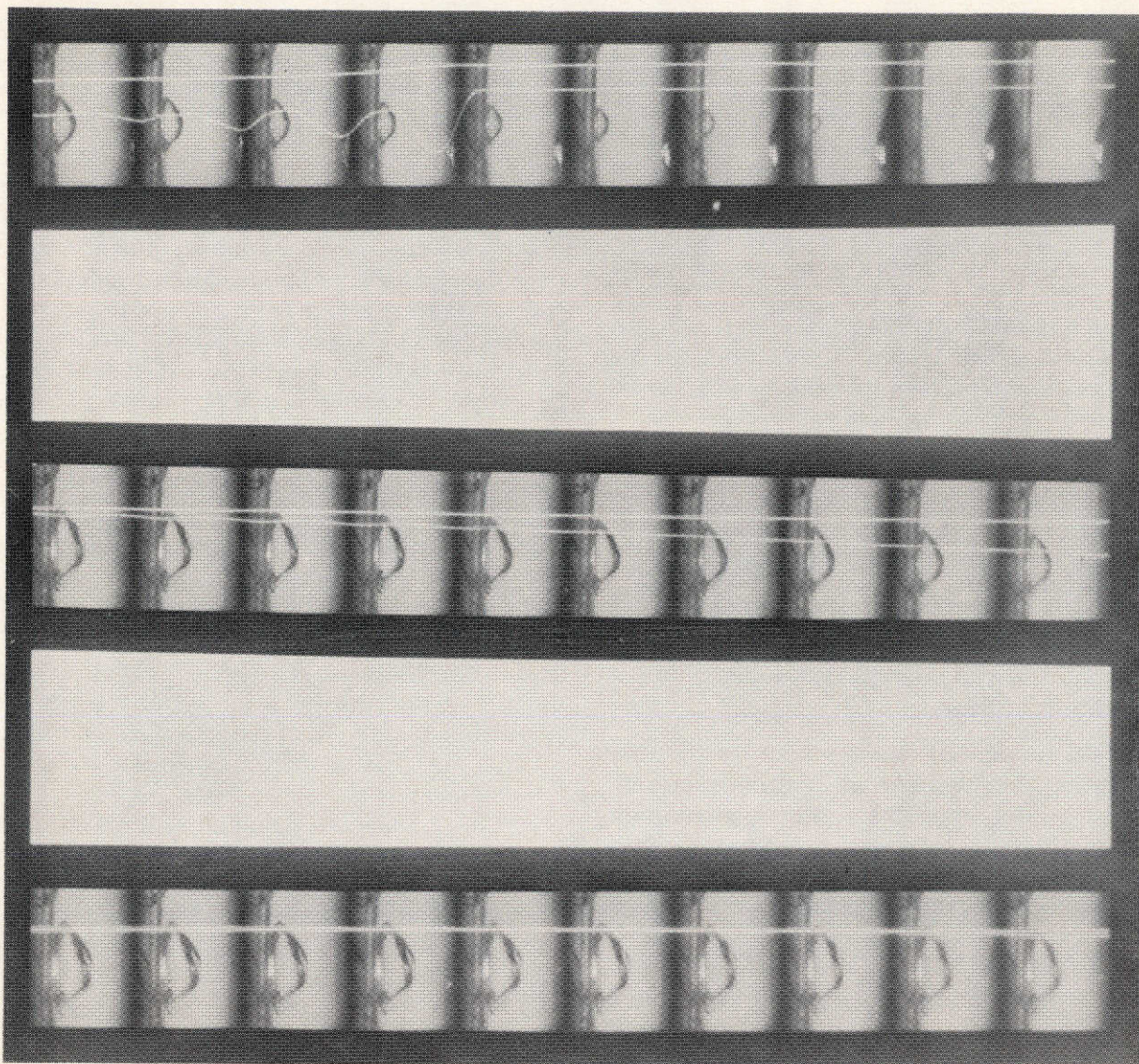
A flow cell is being used for experiments in which the effects of parameters like flow direction and velocity, porous media properties, and fluid physical properties are being investigated. Experimental results are being used to verify a developed mathematical model of the process. The model consists of describing differential equations and algorithms for their numerical solution using a digital computer.

The mathematical model will provide a means of simulating systems such as ground-water reservoirs where salt water-fresh water displacement occurs and hydrocarbon reservoirs where certain secondary recovery processes are being used.

A STUDY OF LOCAL TEMPERATURES DURING NUCLEATE BOILING

Russell Mesler and Chi-Liang Yu
National Science Foundation

The literature on nucleate boiling clearly indicates that bubble departure size is dependent upon surface temperature. However, only average surface temperatures have been measured in these studies. Local transient temperatures can be expected to be of even greater importance. An apparatus has been constructed to permit photographing bubble growth while local temperature is measured with a tiny, fast-response surface thermocouple.



A growing bubble photographed at 4000 frames per second while the surface temperature beneath it and the force it exerts on the surface are being measured. The superimposed white lines are oscilloscope traces and indicate the temperature and force five frames earlier.

MEASUREMENT OF INERTIAL FORCES DURING RAPID BUBBLE GROWTH

Russell Mesler and Roderick Athey
National Science Foundation

Indirect evidence indicates inertia can be important in determining both shape and size of rapidly growing bubbles in nucleate boiling. To study the influence of inertia more directly, a technique of measuring the inertial

force has been devised utilizing a vessel suspended from a piezoelectric force transducer. Boiling occurring in the vessel is photographed with a high speed camera while the force is simultaneously recorded with an oscilloscope photograph.

Preliminary indications are that large inertial forces do correlate with larger departure sizes.

NUCLEATE BOILING OF BINARY MIXTURES

Russell Mesler, Ugersain Chopra and
Jon Donovan

National Science Foundation

During bubble growth in nucleate boiling, a microlayer beneath the bubble evaporates into the bubble cooling the surface. The cooling effect has been studied with water and toluene and interesting differences noted. Binary mixtures offer new interesting variations.

The cooling effect is being studied with platinum films, fired on to Pyrex, serving as resistance thermometers.

PRESSURE WAVES FROM COLLAPSING VAPOR BUBBLES

Russell Mesler, Warren Harrel and
William Horigan

National Science Foundation

The collapse of a vapor bubble originates a pressure wave. Measurements with a quartz piezoelectric transducer have shown that the pressure wave contains a negative pulse capable of placing the liquid in tension. The collapse of a vapor bubble generated with a spark is being photographed at 35,000 pictures per sec to support a belief that the negative pressure is itself causing cavitation.

SUDDEN DECOMPRESSION OF LIQUID WATER TO A SUPERHEATED STATE

Russell Mesler and Joseph Parrish

National Science Foundation

When liquid water in shallow pools is suddenly decompressed to a superheated state the liquid begins to boil. In the first 20 msec or so the pressure in the liquid falls to a value which can be appreciably above that in the low pressure reservoir to which the pressure is relieved, particularly for higher superheats.

High speed motion pictures of the decomposition in a transparent vessel are being taken to discriminate between postulated mechanisms.

REACTION OF METALLIC SODIUM WITH WATER

Russell Mesler and Kelvin Flory

University of Kansas

It is well known that sodium metal can react explosively with water, but few details of the reaction have been reported. Findings indicate that a significant delay occurs which suggests that the sodium is dispersed just before the explosion by mechanisms similar to those postulated to account for molten metals exploding with water.



CIVIL ENGINEERING

Robert L. Smith, Chairman

Civil Engineering research at The University of Kansas is made an integral part of the graduate academic effort for both the M.S. and Ph.D. programs. At the present time, the Department is responsible for the administration of the following graduate programs, all of which incorporate significant participation in departmental research efforts:

1. Civil Engineering
2. Engineering Mechanics
3. Environmental Health Engineering
4. Environmental Health Science
5. Water Resources Engineering
6. Water Resources Science

Research activities within the Department center around structural mechanics (both experimental and theoretical), materials (primarily soils, metals, and concrete), engineering hydrology, fluid mechanics, waste water treatment, and solid waste disposal.

Research support derives from a variety of sources including federal and state agencies and private industrial organizations. Contract research adaptable to the University environment is encouraged because it provides a basis for bringing both faculty and students into contact with the real work problems facing specific areas of civil engineering. Departmental research facilities are extensive. They include the C. L. Burt Environmental Health Laboratory, a large and very versatile structural testing laboratory, a soils laboratory, a highway materials laboratory, a concrete laboratory, a water resources laboratory, a hydraulics laboratory, and an experimental stress laboratory. Overall, these laboratories provide more than 30,000 square feet of modern laboratory space and provide ample opportunity for meeting basic departmental objectives concerning integration of the research and teaching programs.

A significant portion of the departmental research effort is described under sections of this report relating to the Environmental Health Laboratory and the Water Resources Institute.

UNSTEADY FLOW IN A PIPE-ORIFICE

Yun-Sheng Yu and Chia-Hsiung Tai

University of Kansas

Time-dependent, laminar incompressible flow in a pipe-orifice is being investigated theoretically and experimentally. A numerical scheme has been developed to determine the instantaneous velocity distribution in the neighborhood of the orifice when a time-dependent differential pressure is applied to the system. The limited numerical results show that the time step must be kept small (preferably less than 0.005 second) for the numerical scheme to be convergent and stable. An experimental apparatus for oscillatory flow in a pipe-orifice is now being calibrated.

VIBRATIONS OF STEEL JOIST-CONCRETE FLOOR SLAB FLOORS

Kenneth H. Lenzen and Richard R. Moderow
Steel Joist Institute

During the last year the vibrations of many buildings' floor systems have been measured. This research, which was conducted from Chicago to Hawaii, was to consolidate findings, verify calculations, bridging, and reaffirm the recommendations made previously. While this research was underway, additional investigations were being made into the effect of the

support girder, of composite action, of gypsum floors, and of unsymmetrical or disarrayed floors. The results of these tests and the substantiation of the laboratory tests have been presented to the Steel Joist Institute Engineering Practice Committee for action. Within this report are tables for recommended design charts and acceptable designs which minimize vibration problems in open areas.

INTERACTIONS BETWEEN NAVIGATION CHANNELS AND SHIP TRAFFIC

John S. McNown and V. Phillip Soice
University of Kansas Research Grant

Various hydraulic phenomena occur in the constricted spaces around large barge tows moving in restricted waterways. The initial phase of this study was the collection and analysis of published information on increases in the sinkage and resistance of the ships caused by the canal boundaries. The available information shows these effects to be physically and economically important but not yet adequately predictable. In exploratory experimental studies, (a) the effect of canal size on the virtual mass of the system was found to be less than anticipated and difficult to measure accurately; and (b) the wave velocity in channels with various cross sections was found to be predictable from the average depth ($c = \sqrt{gy'}$ in which y' is the cross-sectional area of the channel divided by the surface width).

DESIGN OF SIGN STRUCTURES FOR THE INTERSTATE SYSTEM

Kenneth H. Lenzen and Bruce F. McCollom
In Cooperation with the Kansas State
Highway Department

The structures supporting signs on interstate systems require a span in excess of 100 feet and from 20 to 50 feet above the roadway. Since this is a three-dimensional structure, it must support the wind, impacts, and snow loads to which it is exposed; further, it should be an economical structure. The American Association of State Highway Officials wrote a tentative set of specifications for a program

on sign structures. Earl Wilkinson, Bridge Engineer for Kansas, was a member of this specifications committee. However, insufficient data was available to totally define the force on such structures. A refinement of these specifications will be made and it is probable that designs which result from this project will be used throughout the state. Mr. Wilkinson and Dr. Nicholas Willems (Civil Engineering, KU) are working with the two investigators in determining the proper design.

STATIC ANALYSIS OF CABLE SUPPORTED STRUCTURES

Nicholas Willems and Thomas M. Murray
ARMCO

Based on an experimental study concerning the stress-strain characteristic of cables, a study was made on using direct energy minimization techniques to analyze the behavior of cable supported structures. Included in the formulation of the problem were the effects of finite geometry changes, support movements, temperature changes and non-linear material properties. An extensive numerical study of various types of cable structures was conducted including their ultimate load capacities. An experimental program was conducted to determine the load-development relationships of typical structural cables to confirm theoretical results.

STRESS-STRAIN CHARACTERISTICS OF CABLES

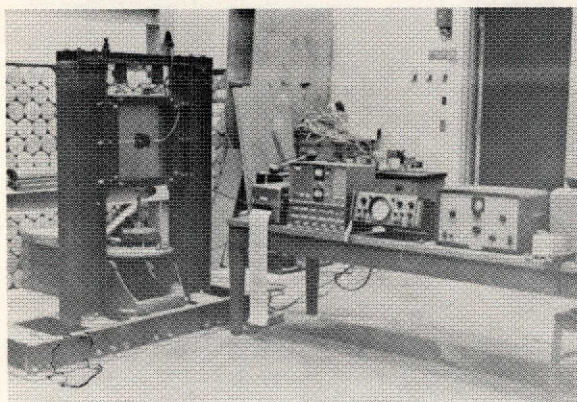
N. Willems and Daniel W. Keene
ARMCO

Determining the stress-strain characteristics of cables is the objective of this experimental study. Actual tests on cables have been carried out to determine their behavior. Stress-strain curve relationships were developed based on the Ramberg-Osgood approach. This study was used to develop a mathematical model to analyze intricate cable supported structures using an energy minimization technique.

PARAMETRIC RESONANCE OF STIFFENED RECTANGULAR PLATES

Nicholas Willems and Roger C. Duffield
NASA

The theoretical and experimental analysis of stiffened rectangular plates subjected to in-plane periodic normal loading was completed.



Apparatus for experimental analysis of stiffened rectangular plates.

PARAMETRIC INSTABILITY OF STIFFENED CYLINDRICAL PANELS

Nicholas Willems and Everett H. Prewitt
University of Kansas

This study involved the determination of the regions of parametric instability of cylindrical stiffened panels subjected to periodic in-plane normal and shear loading. Considering the stiffeners as discrete elements, use was made of the Galerkin method to solve Donnell's equations of motion. It was found that variations in the stiffener size and the loading arrangement could have a pronounced effect on the location and widths of the regions of instability.

PARAMETRIC RESONANCE OF SKEW STIFFENED PLATES

Nicholas Willems and Ronald G. Merritt
University of Kansas

The purpose of this investigation was to obtain regions of principal resonance for low order spatial modes of simply supported skew stiffened plates loaded periodically in their

plane. The method of averaging was used to reduce the original nonautonomous equation of motion to an equation that was autonomous in the first approximation. A modified perturbation technique was used to determine the eigenvalues and, subsequently, the principal regions of resonance. The effect of the angle of skewness and stiffener configuration on principal regions of resonance was thoroughly investigated.

EFFECTIVE UTILIZATION OF YIELD STRENGTH

S. T. Rolfe, J. T. Easley, and Charles Royer
Pressure Vessel Research Committee of the
Welding Research Council

This research is being conducted to study the effects of strain-hardening and the yield-strength to tensile-strength ratio on the various failure modes of pressure vessels. In particular, this program will investigate whether or not high-yield-strength steels can be more effectively and safely utilized in pressure-vessel applications than present design criteria permit. Initially, the effects of stress concentrations (welds and a representative nozzle geometry) on the bursting behavior of cylindrical specimens fabricated from steels having a wide range of yield strengths and strain hardening exponents will be studied.

AUTOMATIC OPTIMIZATION DESIGN OF MULTI-STORY FRAMES FOR WORKING STRESSES

B. O. Kuzmanovic, N. Willems, and J. C. Alberts
University of Kansas

The elastic moment distribution method is not best suited for the optimum design of multi-story frames. The usual procedure of assuming, in advance, various relative stiffnesses and holding these constant throughout the complete process of cycling when carrying out a moment distribution eliminates the possibility of reducing computer time and core size. For each pattern of relative stiffnesses the frame moments have to be obtained, the actual design completed, and the results compared to make a decision for the next step of optimization. Obviously, this is not an economical approach.



Strain measurements of composite slab system.

Formulas have been developed making it possible to write down the frame moments of a simple portal frame for a given loading system without going into an actual moment distribution. In this manner it is possible to change the relative stiffnesses automatically and to obtain the final moments for the purpose of design comparison without much work. The idea will be extended to multi-story frames by subdividing frames as was done for plastic moment distribution.

REDISTRIBUTION OF MOMENTS IN CONTINUOUS COMPOSITE FLOOR SYSTEMS

N. Willems, Bruce Dickson, Xavier Williams
Jack Gillum & Associates, Kansas City Structural Steel, and ARMCO

Research objectives have been to investigate and redistribute moments so as to fully utilize the positive moment capacity of com-

posite beam-floor systems. A full-scale laboratory model is being tested to determine actual deflections and moment distributions. On the basis of this first-stage testing, the rotational resistance of beam-column connections will be reevaluated and tested.

AEROBIC SURFACE STABILIZATION OF REFUSE
Ross E. McKinney and Timothy Tilsworth
Office of Solid Wastes, U.S. Public Health Service
(See Environmental Health)

WATER QUALITY FROM A RURAL WATERSHED
Ross E. McKinney and Gerald A. Stoltenberg
Kansas State Health Department
(See Environmental Health)

PURE OXYGEN ACTIVATED SLUDGE SYSTEM
Ross E. McKinney and Alex A. Thomopoulos
Air Products and Chemical Corporation
(See Environmental Health)

DIFFUSED AERATION MODEL STUDIES
Ross E. McKinney and Daniel W. Smith
Federal Water Pollution Control Administration
(See Environmental Health)

ANAEROBIC-AEROBIC CYCLES IN ACTIVATED SLUDGE SYSTEMS

Ross E. McKinney and Robert B. Barbour
City of Johannesburg, South Africa
(See Environmental Health)

TEMPERATURE EFFECT ON ACTIVATED SLUDGE

Ross E. McKinney and Christina Palmerlee
Federal Water Pollution Control Administration
(See Environmental Health)

NUTRIENT REMOVAL BY ACTIVATED ALGAE

Ross E. McKinney and E. Corbin McGriff, Jr.
Federal Water Pollution Control Agency
(See Environmental Health)

ROTOR AERATOR MODEL STUDIES

Ross E. McKinney and C. W. McLaughlin
Office of Solid Wastes, U.S. Public Health Service
(See Environmental Health)

ROTOR AERATOR FIELD STUDIES

Ross E. McKinney and Ford Bohl
Federal Water Pollution Control Administration
(See Environmental Health)

REMOVAL OF ALGAE FROM OXIDATION POND EFFLUENTS

Ross E. McKinney and D. M. Martin
Federal Water Pollution Control Administration
(See Environmental Health)

AEROBIC MICROBIOLOGY IN DECOMPOSING REFUSE

Ross E. McKinney and J. L. Mahloch
Office of Solid Wastes, U.S. Public Health Service
(See Environmental Health)

MECHANISMS OF REACTIONS FOR POLYELECTROLYTES

Ross E. McKinney and Flin C. McGhee
National Science Foundation
(See Environmental Health)

A WATER QUALITY MODEL FOR MIDWESTERN STREAMS

Walter J. O'Brien and Lynn E. Couch
Environmental Protection Agency
(See Environmental Health)

ESTABLISHING A SANITARY LANDFILL

Ross E. McKinney and Sanford M. Brown, Jr.
City of Lawrence, Kansas
(See Environmental Health)

RESPONSE OF ACTIVATED SLUDGE SYSTEMS TO VARIATIONS IN THE CONCENTRATION OF SUSPENDED SOLIDS IN THE INFLUENT

Walter J. O'Brien and Richard F. Luthy
Environmental Protection Agency
(See Environmental Health)

USE OF FLY ASH FOR TREATMENT OF WASTE STABILIZATION POND EFFLUENT

Walter J. O'Brien and Michael D. Turvey
Environmental Protection Agency
(See Environmental Health)

ANALYSIS OF AN INDUSTRIAL EFFLUENT

Ross E. McKinney and Pamela K. Mintz
Federal Water Pollution Control Administration
(See Environmental Health)

AN EVALUATION OF AN ELECTROSTATIC DESCALER

Ross E. McKinney, Carl E. Burkhead and Martin Trnovsky
Armco Steel Corporation, Kansas City, Missouri
(See Environmental Health)

ENVIRONMENTAL PHYSIOLOGY OF FRESH WATER PLANKTONIC CRUSTACEA

Kenneth B. Armitage and Chi-Hsiang Lei
Kansas Water Resources Research Institute
(See Water Resources)

HIGHWAY STORM DRAINS

John S. McNown and Chi-Hsiung Tai
Kansas Water Resources Research Institute
(See Water Resources)

PARTITION COEFFICIENTS FE, MN, CO, NI, CU, ZN-RIVER WATER, SUSPENDED LOAD

Ernest E. Angino, L. M. Magnuson, T. Evans
Kansas Water Resources Research Institute
(See Water Resources)

WATER QUALITY CONTROL VERSUS RESIDENTIAL RESERVOIR DEVELOPMENT

Sherman M. Wymann, Louis E. Striegel, Nicholas J. Elliot, Conall D. O'Leary
Kansas Water Resources Research Institute
(See Water Resources)

DETERMINATION OF DISCHARGE-FREQUENCY RELATIONSHIPS FOR SMALL DRAINAGE AREAS

Robert L. Smith, James Banks, Michael Berry, Kirke Larson
Kansas Water Resources Research Institute
(See Water Resources)

WEATHER UTILIZATION ASPECTS OF WEATHER MODIFICATION AS APPLIED TO KANSAS

Robert L. Smith, M. Bansal, I-Lung Cheng
Kansas Water Resources Research Institute
(See Water Resources)

THE DEVELOPMENT AND FIELD TESTING OF A BASIN HYDROLOGY SIMULATOR

D. W. Green, E. C. Pogge, J. Halepaska, R. Knapp, D. Richards, B. Schorn, and M. C. Huang
Kansas Water Resources Research Institute
(See Water Resources)

NUMERICAL MODELING OF UNSATURATED GROUND-WATER FLOW INCLUDING EFFECTS OF EVAPOTRANSPIRATION

D. W. Green, H. Dabiri, J. D. Khare, and J. Collins
Kansas Water Resources Research Institute
(See Water Resources)

**LONGITUDINAL DISPERSION AND REAERATION IN
NATURAL STREAMS**

Yun-Sheng Yu and M. K. Bansal
Kansas Water Resources Research Institute
(See Water Resources)

**USE OF LIME-SODA ASH SLUDGE FOR THE
TREATMENT OF MUNICIPAL WASTEWATER**

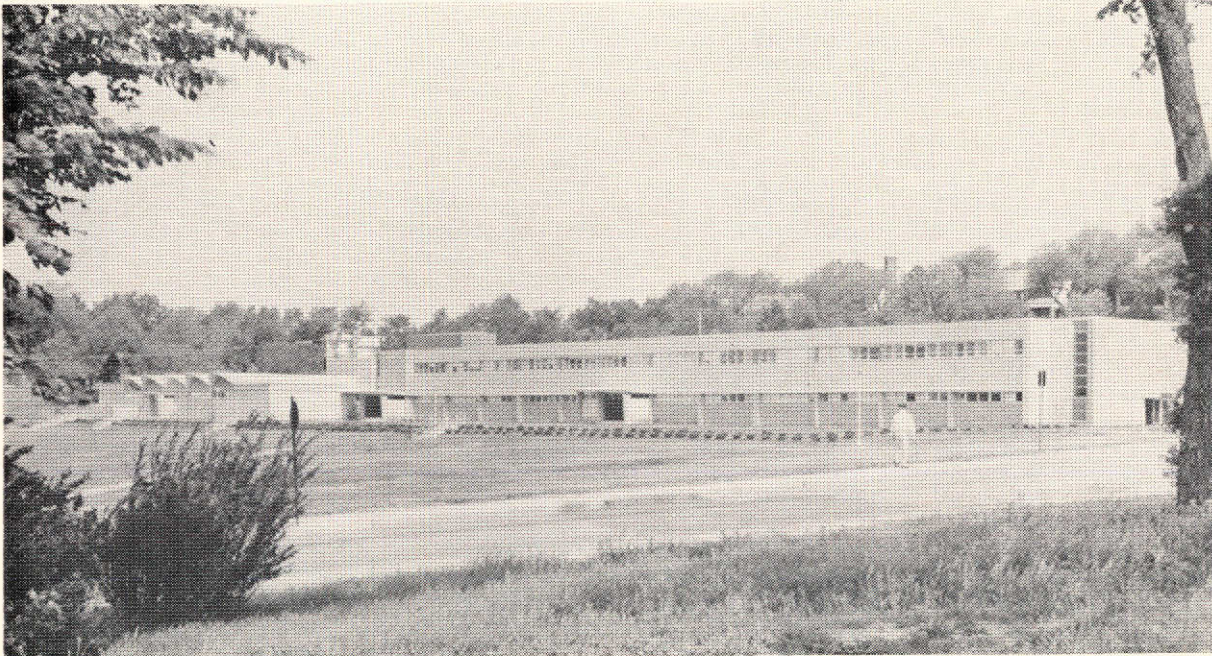
Walter J. O'Brien and James W. Moore
Kansas Water Resources Research Institute
(See Water Resources)

**AN ECONOMIC MODEL OF AN AREA'S RESPONSE TO
DEPLETION OF ITS WATER RESOURCE**

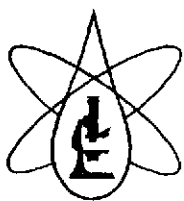
R. W. Ruppert, G. S. Clausen, J. H. Hoag
Kansas Water Resources Research Institute
(See Water Resources)

**DISPOSAL OF HEATED WATER THROUGH
GROUND WATER SYSTEMS**

G. P. Willhite, F. Simonpietri, and Jay Stoker
Kansas Water Resources Research Institute
(See Water Resources)



Learned Hall, erected in 1963, houses Civil, Electrical, and Aerospace Engineering.



ENVIRONMENTAL HEALTH

Ross E. McKinney, Director

The emphasis on environmental pollution control continues to grow as our population and industrial technology increases. No longer can our rivers and lakes absorb all of our liquid wastes without proper treatment. The air around us has limited capacity for gaseous wastes and the land where we live must accept all of our solid wastes. The Environmental Health Research Laboratory has continued to direct attention towards developing new and improved methods for waste treatment. Special concern has been given to environmental pollution problems occurring in Kansas.

Graduate students with diverse backgrounds in chemistry, biology and engineering have the opportunity to plan and to carry out research on almost every aspect of environmental pollution control. Starting with an environmental pollution problem, the students examine past experience as indicated in the literature while evaluating the waste characteristics. A number of approaches are examined from a theoretical viewpoint. The objectives of waste treatment are evaluated for the wastes or waste system in question. Laboratory experiments are designed and set up to demonstrate the value of the approach selected. If the laboratory studies indicate significant improvement over existing waste treatment methods, efforts are then directed towards field scale studies either as a pilot plant or full scale. These field studies demonstrate the value of the proposed system in solving the waste problem. Eventually, reports are prepared and added to the literature to assist other researchers in solving similar environmental pollution problems.

In the past, environmental pollution control research was concerned almost entirely with the technical aspects of the problem. Chemistry, biology and engineering furnished all of the information needed to solve the pollution problems. Today, this approach is not adequate. Purely technical solutions are not

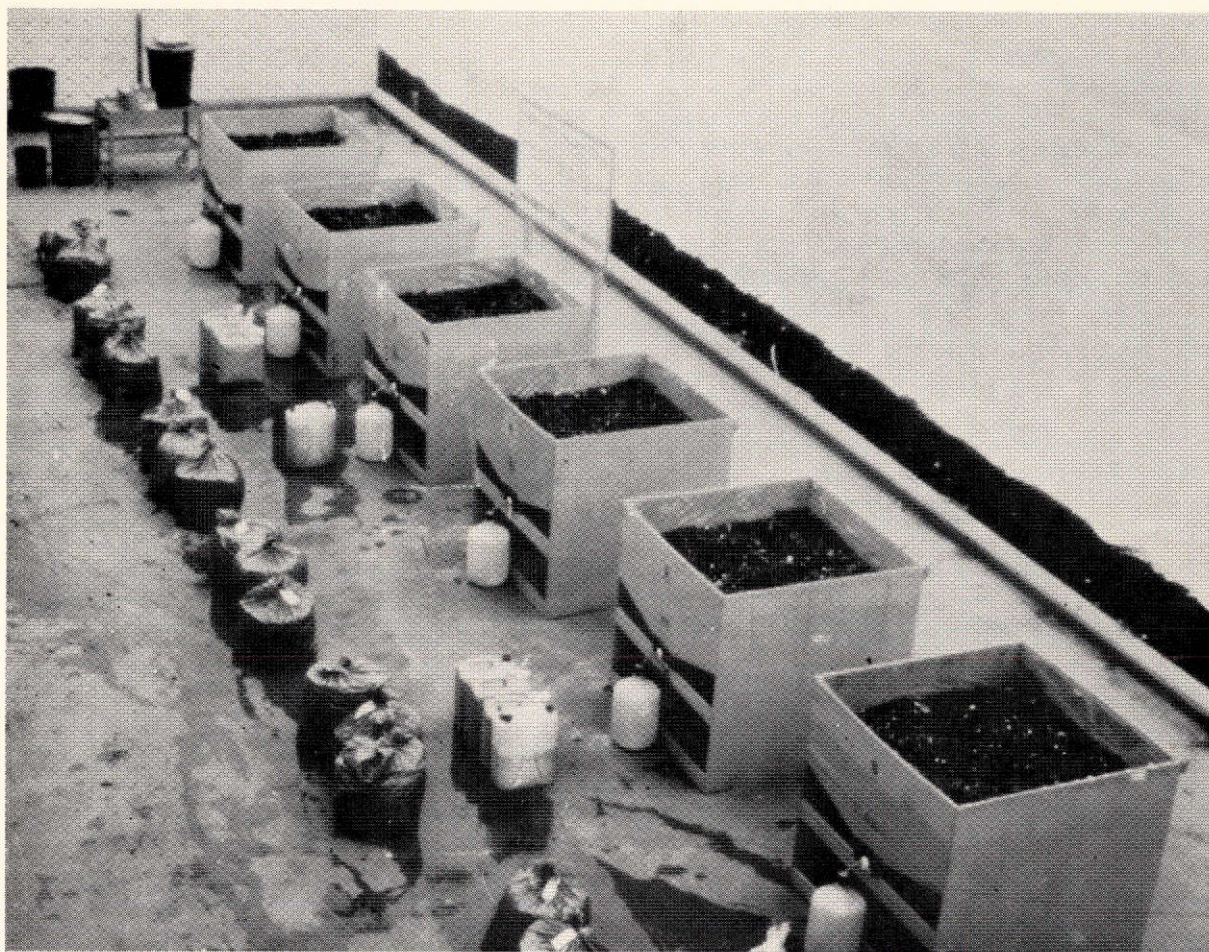
enough. Environmental pollution problems involve social and political aspects that determines the applicability of technical solutions. It is equally important to research the people problems associated with the technical problems of pollution control management. In this way, the efforts of the Environmental Health Research Laboratory are continuously changing to meet new challenges designed to keep the environment in Kansas at the highest possible quality.

AEROBIC SURFACE STABILIZATION OF REFUSE

Ross E. McKinney and Timothy Tilsworth
Office of Solid Wastes, U.S. Public Health Service

The purpose of this study was to examine the feasibility of aerobic surface stabilization of domestic refuse. Refuse was collected from the Lawrence sanitary landfill; and the inert solids such as glass, plastics, and metal were separated out. The remaining material was ground and mixed with various additives prior to disposal on the surface of the ground.

A series of six wooden boxes were constructed, 4 ft. on each side. A layer of sand and gravel was placed in the bottom of each box to support the refuse. The six boxes contained: refuse only; refuse+primary sewage sludge; refuse+digested sewage sludge; refuse+vacuum filtered sewage sludge; refuse+lime treated primary sludge; and refuse+fertilizer. All test units were outside, exposed to normal rainfall and weather variations. It was observed that the refuse was stabilized quickly within 30 days during warm weather and 120 days during cold weather. The addition of nutrients appeared to assist stabilization in the cold weather. The major drawback to sur-



Surface stabilization of refuse offers new method of solid wastes treatment.

face stabilization was cost. It was estimated to cost between \$5 and \$7/ton of refuse processed. The major advantage was the fact that a given landfill site could be used over and over again. Where land is scarce, the aerobic surface stabilization process offers a definite solution to the solid waste disposal problem.

WATER QUALITY FROM A RURAL WATERSHED

Ross E. McKinney and Gerald A. Stoltenberg
Kansas State Health Department

With increased emphasis on stream water quality, it is important to recognize the pollution contribution of rural areas as well as

urban areas. This research project was designed to determine the water quality parameters from a rural watershed containing only normal agricultural operations for eastern Kansas. Runoff from the Soldier Creek watershed above Topeka, Kansas, was examined over a one-year period to determine the quantity of major contaminants discharged from this basin.

Examination of the bacteriological data indicated that fecal coliforms were a major fraction of the coliform population in this area. During periods of high runoff the coliform counts increased rather than decreased, indicating a washoff of coliforms from the land. Runoff also affects the BOD and the dissolved oxygen in the stream. The data

indicated approximately 3 million pounds of BOD were being discharged annually to the Kansas River from Soldier Creek.

Since nitrogen and phosphorus are important elements in eutrophication as well as in agriculture, efforts were directed towards determining the loss of these materials from the watershed. Approximately 2.2 million pounds of nitrogen and 0.7 million pounds of phosphate were applied to this watershed during this study. Approximately 28% of the nitrogen and 34% of the phosphate applied to the land were carried off by runoff. Thus, agricultural drainage appeared to be an important source of nitrogen and phosphorus in the streams and rivers in eastern Kansas.

This study clearly demonstrated that agricultural drainage is as important in water quality as urban drainage. While water pollution control agencies have concentrated their efforts on urban drainage, it appears that attention will soon have to be focused on agricultural drainage if real progress is to be made.

PURE OXYGEN ACTIVATED SLUDGE SYSTEM

Ross E. McKinney and Alex A. Thomopoulos
Air Products and Chemical Corporation

With increased interest in the use of pure oxygen in biological waste treatment systems, efforts were directed to determine the validity of the complete mixing activated sludge (CMAS) process with pure oxygen in place of air. Three laboratory pilot plants were constructed and fed domestic sewage. One unit was fed pure oxygen; one unit was fed air under pressure; and one unit was open to the atmosphere and acted as the control unit.

The loads on the treatment systems were controlled by adjusting the liquid retention time in the aeration cell. The aeration period was reduced from 4 hours to 3 hours to 2 hours to 1 hour and, finally, to $\frac{1}{2}$ hour. It was found that these systems followed the basic concepts of CMAS systems. Unfortunately, the small size of the pilot plants adversely affected the return sludge control, preventing maintenance of adequate MLSS in the aeration tanks. The net effect of the

deficiency of MLSS was incomplete treatment of the wastes. This was very critical during the short retention period.

Examination of the data indicated that there were no significant differences in the three units when operating at low loading rates. Because of the increased solubility of oxygen in the pure oxygen system over the air system, it was possible to increase the organic load on the pure oxygen system over that of the air system. Overall, the effluent quality depends upon the suspended solids in the effluent and the MLSS concentration needed to insure complete metabolism of the organic matter in the wastewaters.

While CMAS systems will work with pure oxygen, improved design with mechanical aeration systems will make it difficult for pure oxygen to compete economically with air for domestic sewage. For strong industrial wastes, pure oxygen should have an economic advantage.

REMOVAL OF ALGAE FROM OXIDATION POND EFFLUENTS

Ross E. McKinney and D. M. Martin
Federal Water Pollution Control Administration

Oxidation ponds have found extensive use for low cost sewage treatment from small communities. With increasing emphasis on high quality stream criteria, concern has been raised about the continued use of oxidation ponds since the effluent is not always of high quality. Examination of the oxidation pond effluent indicated that the effluent quality was largely related to the algae in the effluent stream. The aim of this research was to determine the value of a shallow rock filter in removing the algae from the oxidation pond effluent.

A laboratory study was carried out with three upflow rock filters, 3 feet long. The best system yielded 80-90% reduction in algae. It appeared that a simple upflow rock filter had merit for improving the effluent quality from oxidation ponds to a point where oxidation ponds could continue to find extensive use for small communities. The simplicity of the design and operation of the rock filter warrants further study.

DIFFUSED AERATION MODEL STUDIES

Ross E. McKinney and Daniel W. Smith
Federal Water Pollution Control Administration

The object of this study was to develop basic relationships for evaluating diffused aeration systems employing hydraulic models. Three aeration tanks were used to study the effect of varying water depth, air flow, and air diffuser depth. The three tanks were cubical with basic dimensions of 1 ft., 2 ft., and 4 ft. on a side.

The primary evaluation was carried out with tap water and sodium sulfite with the oxygen transfer coefficient, K_{La} , being used as the dependent variable. Air flow rates were varied from 0.05 to 0.5 cfm/cf aeration tank volume. The results confirmed the findings of previous investigators who had found that K_{La} was proportional to the air flow rate.

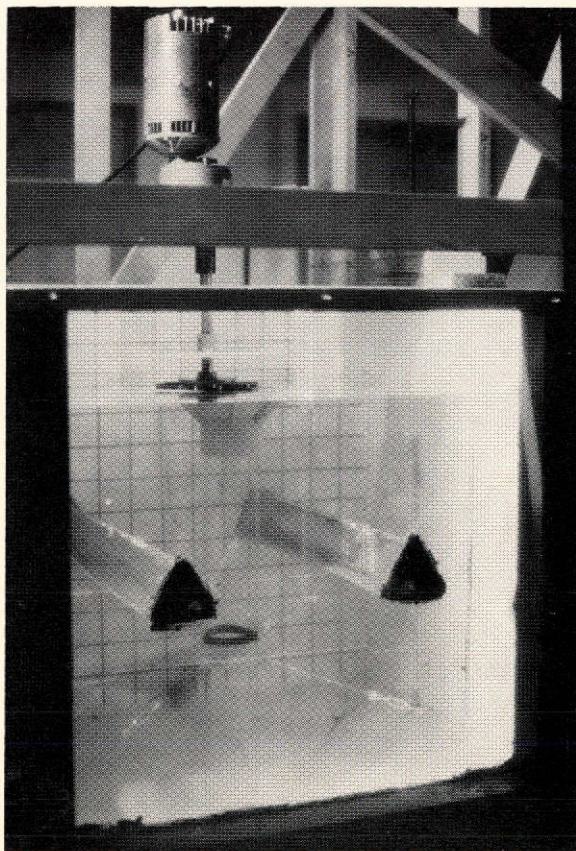
Diffuser depth is very important in determining K_{La} , for a given aeration tank. Increasing the diffuser depth results in increas-

ing K_{La} . The air produces an air lift pump, forcing the water around the tank faster with greater depth. As the tank width increases beyond tank depth, K_{La} is reduced, indicating mixing problems. Water depth determines tank geometry and fluid flow patterns. K_{La} is directly proportional to water depth for a given system.

Examination of the data statistically with the aid of the GE 635 computer yielded the following relationship:

$$K_{La} = 28.6 G^{0.82} \left[\frac{1}{v} \right]^{1.06} d_d^{0.724}$$

This general relationship should be valuable in helping engineers evaluate diffused aeration systems. In the past, engineers have employed aeration equipment on a trial and error basis with little regard to sound design parameters. The uniformity of design permitted reasonable design criteria to produce the desired results. With changes in tank design, problems have arisen with diffused aeration systems. This design relationship developed from model concepts should help engineers improve full scale plant design.



Aeration tank studies yield design data for full scale installation.

TEMPERATURE EFFECT ON ACTIVATED SLUDGE

Ross E. McKinney and Christina Palmerlee
Federal Water Pollution Control Administration

One of the major factors affecting activated sludge systems is temperature. Data have shown that bacterial metabolism is reduced by a factor of two with each 10°C decrease in temperature. Little data exists for temperatures between 0°C and 5°C. In an effort to ascertain the effect of temperature, laboratory activated sludge systems were set up using soluble organic wastes. The rate of organic removal and the synthesis of new microbial solids were measured in batch-fed units at 28°C, 25°C, 21°C, 5°C, 4°C, and 1°C. The impact of temperature on the activated sludge metabolism was clearly demonstrated in these units.

Continuously fed activated sludge systems demonstrated that both the low temperature unit and the high temperature unit produced the same degree of metabolism. The low temperature system had higher MLSS, permitting a higher microbial population to compensate

for the lower temperature. The results confirm the field observations that winter operations to not deviate significantly from summer operations provided the MLSS are increased accordingly.

ROTOR AERATOR MODEL STUDIES

Ross E. McKinney and C. W. McLaughlin
Office of Solid Wastes, U.S. Public Health Service

The application of rotor aerators for the treatment of hog manure in the United States originated in Lawrence at the Paul Smart Pork Farm with the first installation in January 1966. Equipment designed and constructed for the initial farrowing house performed satisfactorily but was considered too expensive for use in the other buildings. Two equipment manufacturers designed and supplied mechanical aerators for the other buildings, but this equipment failed to perform satisfactorily and broke down. The entire success or failure of this hog manure treatment concept depended upon continuous operation of the rotor aerators.

In an effort to solve the problem created by the existing rotor aerators, a new rotor aerator was designed. In an effort to determine the value of the new rotor aerator, a laboratory, hydraulic model of the hog manure treatment system was constructed from leucite plastic using a 12:1 geometric ratio. Models were constructed of the existing rotor aerator and the proposed rotor aerator and operated under different depths of submergence. The proposed rotor aerator model demonstrated greater oxygen transfer than the existing rotor aerator model.

ROTOR AERATOR FIELD STUDIES

Ross E. McKinney and Ford Bohl
Federal Water Pollution Control Administration

Success of the laboratory model rotor aerator prompted the design of a full scale rotor aerator. The full scale aerator was designed with a 5 ft. diameter, a 3 ft. length, and two rows of paddles. The paddles were flat plates, 2 inches by 6 inches, set at 4 inch centers in alternating patterns. The rotor was driven by a 7.5 HP motor through a gear reducer to

produce 70 RPM with a submergence of 10 inches.

Two units were constructed, one having a steel cover with a gear drive and the other having a wood and fiberboard cover with a jack shaft reducer. The two units were tested in a new hog building using sodium sulfite and tap water. Power measurements were made and the aerators were evaluated at varying operation depths.

In an effort to determine the optimum number of paddles required, a rotor was constructed with removable blades. It was found that the inner row of blades could be removed without affecting total oxygen transfer characteristics. The blade spacing was further shifted from 4 inches center, to center, to 8 inches.

With normal operation in 12 inches of water and 10 inches submergence, the new rotor aerator can transfer better than four pounds of oxygen per horsepower hour in pure water at 20°C. This oxygen transfer exceeds all other commercially available equipment for hog manure treatment. Not only was the new rotor more successful in oxygen transfer, but it eliminated the operational problems and significantly reduced maintenance requirements. Currently, the Paul Smart Pork Farm has installed 24 rotor aerators employing the new design and has found them superior to the previous aerators.

ANAEROBIC-AEROBIC CYCLES IN ACTIVATED SLUDGE SYSTEMS

Ross E. McKinney and Robert B. Barbour
City of Johannesburg, South Africa

Field observations had indicated that activated sludge systems could undergo anaerobic-aerobic cycling without loss of effluent quality. Efforts were directed toward duplication of this phenomenon in the laboratory.

A tube aeration system was constructed with diffused aeration supplying both the mixing and the aeration. Unfortunately, the time of travel through the aeration system was shorter than that in the field, making duplication of operating conditions impossible. It was not possible to produce the anaerobic-aerobic cycling. As the organic load increased, the treatment system operated normally until

oxygen was limiting. Microscopic examination of the activated sludge permitted rapid evaluation of the treatment system. The protozoa present in the MLSS reflected the chemical quality of the system. When the dissolved oxygen dropped too low, filamentous microbes appeared, creating a problem in solids separation. The overall treatment indicated that dissolved oxygen was necessary for a high quality effluent. When oxygen disappeared from the aeration tank, the effluent deteriorated. Further research is necessary to establish the original objective of this study.

NUTRIENT REMOVAL BY ACTIVATED ALGAE

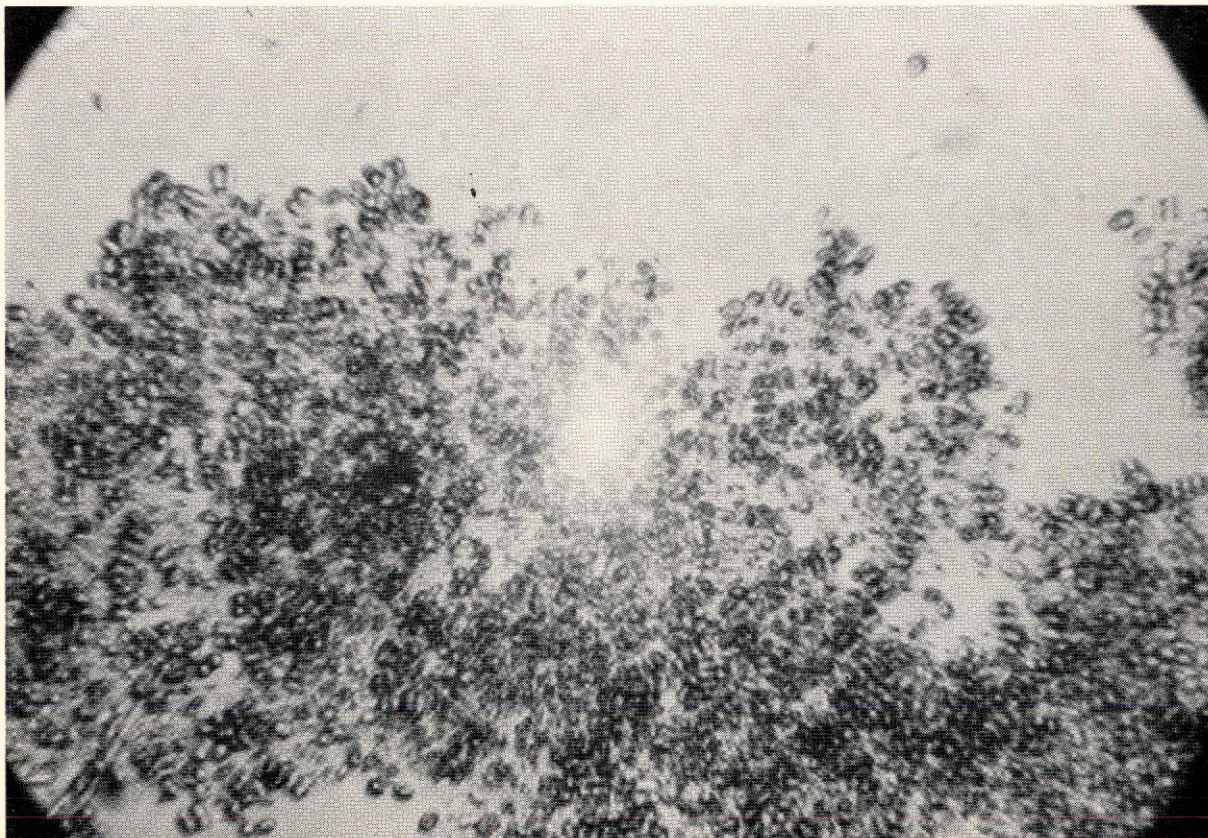
Ross E. McKinney and E. Corbin McGriff, Jr.
Federal Water Pollution Control Agency

Activated algae was developed originally in the Environmental Health Research Lab-

oratory and has been the subject of previous research. This study was conducted in the laboratory to determine the light-dark relationships for activated algae and the treatment efficiencies possible.

The laboratory system consisted of a light reactor and a dark reactor followed by a sedimentation tank for solids separation. Operation with Lawrence domestic sewage was possible with 3.3 minutes retention in the light reactor and 2.4 minutes retention in the dark reactor. The activated algae-sewage mixture was recycled around the system to produce the desired light-dark cycles with a 10 hour waste retention in the treatment unit. The light intensity was maintained at 400 ft. candles. With 1000 to 1400 mg/l MLSS in the activated algae system it was possible to obtain 97% BOD reduction, 92% nitrogen reduction, and 74% phosphorus reduction.

Activated algae has operated successfully in the laboratory with a definite light-dark



Photomicrograph of activated algae which offers unique approach to tertiary wastewater treatment.

cycle. The impact of this light-dark cycle lies in the physical relationships for total tank volume and light surface. The next step is to determine the minimum retention period for the wastes. Research is continuing to find the practical value of the activated algae waste treatment system.

AEROBIC MICROBIOLOGY IN DECOMPOSING REFUSE

Ross E. McKinney and J. L. Mahloch
Office of Solid Wastes, U.S. Public Health Service

Research into the aerobic stabilization of household refuse raised the question as to the microorganisms responsible for stabilizing the various types of organic materials. This study employed three substrates: mixed refuse, paper, and grass and leaves. Chemical analysis and microbiological samples were collected every other day for 48 days. The mixed refuse was metabolized the fastest and paper was the slowest metabolized. The chemical environment was very important for good metabolism.

The nature of the soil-refuse system was such that the heat generated by the microorganisms was retained. Temperature became the simplest means for following the metabolic reactions. The microbiological data indicated that bacteria were responsible for the rapid, initial metabolism. Fungi metabolized the more resistant organic compounds and predominated after the bacteria began to die off, and efforts were made to identify the predominant fungi. This study definitely indicated the importance of proper environmental control for maximum stabilization of solid wastes.

AN EVALUATION OF AN ELECTROSTATIC DESCALER

Ross E. McKinney, Carl E. Burkhead and
Martin Trnovsky
Armco Steel Corporation, Kansas City, Missouri

A laboratory study was conducted to measure the capability of an electrostatic descaler to remove deposited materials from various types of water pipe. A control unit, exactly the same as the test unit except for the descaler, was used to determine the effectiveness of the electrostatic device. Test measure-

ments included weight changes of pipe specimens and water quality changes. The pipe specimens were a part of both the control and test units.

Several test conditions were investigated to simulate actual field conditions where the descaler has found application. These conditions included the effect of grounding, heated water and the nature of the reservoir used in the control and test units.

A WATER QUALITY MODEL FOR MIDWESTERN STREAMS

Walter J. O'Brien and Lynn E. Couch
Environmental Protection Agency

A digital model capable of providing a continuous estimate of runoff and inorganic water quality is being developed. Input to the model consists of historical or simulated rainfall and temperature records. The model computes a complete water budget and allocates the excess rainfall to runoff. Each component of the total discharge brings to the stream a different concentration of dissolved solids.

This concentration is dependent upon the mechanism of movement for the water toward the stream bed and upon the primary source of the dissolved material. Solutes contributed by both the natural geology of the region and by farming operations are considered.

The model is being tested on the Soldier Creek watershed located north of Topeka, Kansas.

MECHANISMS OF REACTIONS FOR POLYELECTROLYTES

Ross E. McKinney and Flin C. McGhee
National Science Foundation

Polyelectrolytes have found increasing use in water and wastewater treatment. Unfortunately, selection of a suitable polyelectrolyte has been largely a matter of trial and error. This study was concerned with examination of fundamental types of polyelectrolytes to permit better understanding of their reactions.

Laboratory studies were carried out with anionic, cationic and non-ionic polyelectrolytes. It was found that polyelectrolytes re-

acted ionically. Like-charged polyelectrolytes did not react; nor was there a reaction between non-ionic polymers and polyelectrolytes. Surface phenomena did not affect polyelectrolyte reactions.

One of the most important environmental factors affecting polyelectrolytes was pH. Cationic polyelectrolytes showed maximum reaction at pH 3-4; while anionic polyelectrolytes operated best at pH levels above 6. This reactivity difference in the acid pH range is believed to be the primary reason for differences of opinion as to proper selection of polyelectrolytes. A slight shift in pH can cause a shift from a cationic polyelectrolyte to an anionic polyelectrolyte. Recognition of this fact should help in the selection of proper polyelectrolytes.

ESTABLISHING A SANITARY LANDFILL

Ross E. McKinney and Sanford M. Brown, Jr.
City of Lawrence, Kansas

Sanitary landfills have been used extensively for solid waste disposal in the United States but are relatively new to Kansas. By and large, Kansans have used open dumps for solid waste disposal with the creation of environmental pollution nuisances and public health hazards. As a net result, Kansans are generally opposed to sanitary landfills as they equate open dumps to sanitary landfills.

The recent history of solid waste disposal at Lawrence, Kansas, demonstrated the problems facing establishment of a sanitary landfill. Previous use of the term "sanitary landfill" had resulted in the public developing a negative attitude toward sanitary landfills. Improper planning and poor operation resulted in the city's need for a new landfill site years earlier than expected. Difficulty in locating a new landfill site demonstrated the need for public relations and demonstration of proper operation of such a landfill.

Current concern over environmental pollution makes it difficult for governmental agencies to make controversial decisions relating to solid waste disposal. While technically feasible, the Lawrence sanitary landfill was delayed for over a year by "people problems" before establishment.

With technical assistance from the Uni-

versity, the City has demonstrated its capability in operating a sanitary landfill without environmental problems. This study clearly demonstrated that the technical aspects of operating a sanitary landfill are of minor significance compared to the social and the political problems sometimes involved in establishing a new sanitary landfill.

RESPONSE OF ACTIVATED SLUDGE SYSTEMS TO VARIATIONS IN THE CONCENTRATION OF SUSPENDED SOLIDS IN THE INFLUENT

Walter J. O'Brien and Richard F. Luthy
Environmental Protection Agency

Activated sludge systems treating either municipal or industrial wastes operate under conditions of continual variation in the flow rate, the organic concentration, and the organic composition of the plant influent. Previous research at this, and other institutions, has been primarily directed toward determining the response of the biological culture to variations in the concentration and the composition of the soluble organic material in waste. However, changes in the concentration of suspended solids entering the aeration basin are daily occurrences in most field installations because of transient short circuiting in the primary sedimentation basin. The objective of this research is to determine the effect of these transients on the performance of the overall system.

The investigation is being conducted in a continuous flow automatically recording respirometer with solids recycle. The influent is untreated municipal sewage. Sludge collected from the primary sedimentation basin is being used to vary the concentration of suspended solids entering the aeration basin. Two size distributions of solids—one obtained by passing the material through a fifteen mesh screen; the other by mixing the sludge in a high speed blender to produce a colloidal suspension—are being investigated.

The oxygen utilization rate, mixed liquor suspended and volatile solids, total and soluble COD, and active mass, are measured in the aeration basin. The total COD, total BOD, and suspended solids in the effluent of the secondary sedimentation basin are also monitored.

Preliminary results indicate a relatively slow increase in respiration rate and essentially no deterioration in effluent quality following a step increase in the concentration of influent suspended solids.

USE OF FLY ASH FOR TREATMENT OF WASTE STABILIZATION POND EFFLUENT

Walter J. O'Brien and Michael D. Turvey
Environmental Protection Agency

Waste stabilization ponds are widely used throughout the midwest for treatment of sewage originating from small municipalities and industrial plants. The effluent from these ponds often contains large quantities of algae which ultimately die and decompose in the receiving stream. This partially negates the benefits of pond treatment. The objective of this research is to examine the feasibility of using fly ash to remove algae from pond effluents.

Laboratory tests are being conducted using effluent from the Linwood, Kansas, waste stabilization ponds. Excellent algal removal has been obtained using a 1.2 meter deep up-flow filter followed by sedimentation. The filter contains a 0.6 meter column of ungraded fly ash. The hydraulic loading is 99 liters per square meter per hour. Three hours of sedimentation are provided.

The laboratory unit has consistently produced total BOD and suspended solids concentrations ranging from 10 to 20 mg/l. Some soluble COD and phosphate reduction is also

obtained. The fly ash must be replaced at approximately 30-day intervals because of the accumulation of organic material in the ash. This material may be useful as a soil conditioner.

An economic analysis of the process is being conducted.

ANALYSIS OF AN INDUSTRIAL EFFLUENT

Ross E. McKinney and Pamela K. Mintz
Federal Water Pollution Control Administration

With environmental pollution increasing, it is important that all industrial discharges into the public environment meet required water quality criteria and do not pose any danger to the health of the public. The purpose of this project was to examine the water quality of the discharge from an industrial plant.

Data gathered over a two-month period indicated that, based on currently accepted water quality criteria, the river effluent posed a definite danger to the environment. It is recognized that dilution would reduce this pollution to acceptable levels; but flow to the river represents a health hazard.

This study demonstrated the need for continuous, careful monitoring of wastewater discharges if a satisfactory environment is to be maintained with normal industrial operations. Where industrial discharges are found to exceed satisfactory water quality, treatment facilities should be designed and put into operation.



WATER RESOURCES

George S. Clausen, Director

The Water Resources Institute operates in conjunction with the Kansas Water Resources Research Institute at Kansas State University to promote interdisciplinary research and training in the fields of hydrology and water resources planning design and management. As an arm of the Office of Water Resources Research in Washington, the Institute provides both financial and administrative assistance to the various investigators.

Work pursued under the auspices of the Water Resources Institute is directed toward the solution of problems which are of concern, first, to the state of Kansas and, second, to the Nation. A close relationship is maintained between the Institute and state water officials to assure that mutual benefit is derived from the Institute's activities.

Currently about one-half of the Institute's principal investigators are from the Civil and Chemical Engineering Departments and the other half are from the social, life, and physical sciences. Since the solution of many water management problems requires the joint input of investigators from different disciplines, the Institute is encouraging multi-disciplinary studies.

Most of the graduate students in Water Resources Engineering and Water Resources Science take an active part in the Institute's activities as research assistants on the various projects.

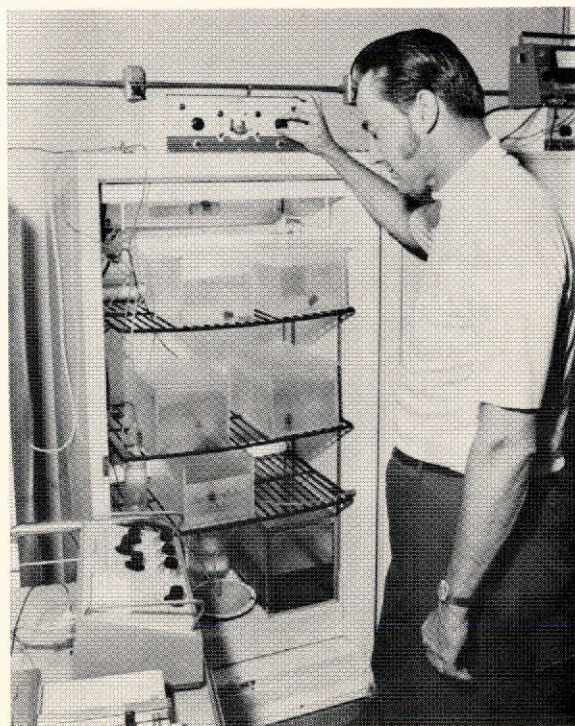
ENVIRONMENTAL PHYSIOLOGY OF FRESH WATER PLANKTONIC CRUSTACEA

Kenneth B. Armitage and Chi-Hsiang Lei
Kansas Water Resources Research Institute

Planktonic crustaceans are poikilothermic animals whose metabolism presumably is temperature-dependent. A temperature-dependent metabolism implies that these kinds of

organisms would be greatly affected by any alteration of the thermal environment by man. Excessive heat may accelerate metabolism beyond the capacity of the demands. On the other hand, warming of cold waters may permit a sustained metabolism and a higher production of these organisms which are important components of aquatic food chains. The metabolic response to temperature may be modified by acclimation; i.e., metabolism may be lowered after exposure to high temperature and raised after exposure to low temperature.

Two planktonic crustaceans, the water fleas *Daphnia ambigua* and *Daphnia galeata mendotae* were cultured at two temperatures,



Apparatus and test specimens used in temperature-metabolism analysis of fresh water planktonic crustacea.

10 and 20C. Metabolism was measured at 5C intervals from 5C to 30C inclusive. *D. ambigua* clearly acclimated to low temperatures by increasing its metabolism at 10 and 15C to a rate similar to that measured at 20 and 25C. Animals acclimated at 20C had greatly depressed metabolism at low temperatures. High temperature acclimation apparently did not occur. By contrast, *D. galeata mendotae* did not evidence any acclimation to low temperature. High temperature acclimation was only slight, but is being further investigated.

Growth studies of *D. galeata mendotae* revealed no differences due to acclimation. Animals grown at 20C reached maturity and produced young several days sooner than animals grown at 10C.

These studies indicate that the effect of temperature on metabolism of *Daphnia* is complex and varies among different species. The metabolism of one species of *Daphnia* cannot be extrapolated to other species for calculation of energy budgets. Studies of ecological energetics of aquatic systems require a more extensive analysis of temperature-metabolism relationships.

PARTITION COEFFICIENTS, Fe, Mn, Ni, Pb, Cu, Zn-RIVER WATER, SUSPENDED LOAD

Ernest E. Angino, L. M. Magnuson, T. Evans
Kansas Water Resources Research Institute

The study of selected heavy metal (Fe, Mn, Ni, Pb, Cu, Zn) partition coefficients between the suspended and dissolved load of streams and the relation to the mineralogical make-up of the suspended load was investigated. The trace element chemistry should provide background and seasonal values for the streams in question. Such data was needed if we are ever to be able to set up water quality standards for the metals in question. It is hoped that this study can shed some light on the effect of the suspended load on the water quality and chemistry of the dissolved load of streams under natural conditions. Each sample from the stations and river systems mentioned in the proposal was studied for the chemical parameters noted, mineralogic make-

up and their relation to the geology of the terrain over which the streams flow. Chemical analyses were made using atomic absorption and emission spectrometry. Interpretation of results is presently in progress. Basic programs for computing and handling atomic absorption spectrometry data (solution phase) and emission spectrographic data (suspended load) have been developed.

DETERMINATION OF DISCHARGE-FREQUENCY RELATIONSHIPS FOR SMALL DRAINAGE AREAS

Robert L. Smith, James Banks, Michael Berry, Kirke Larson

Kansas Water Resources Research Institute

This project continues earlier work of the investigators directed toward development of flood frequency analysis based on modified rational concepts.

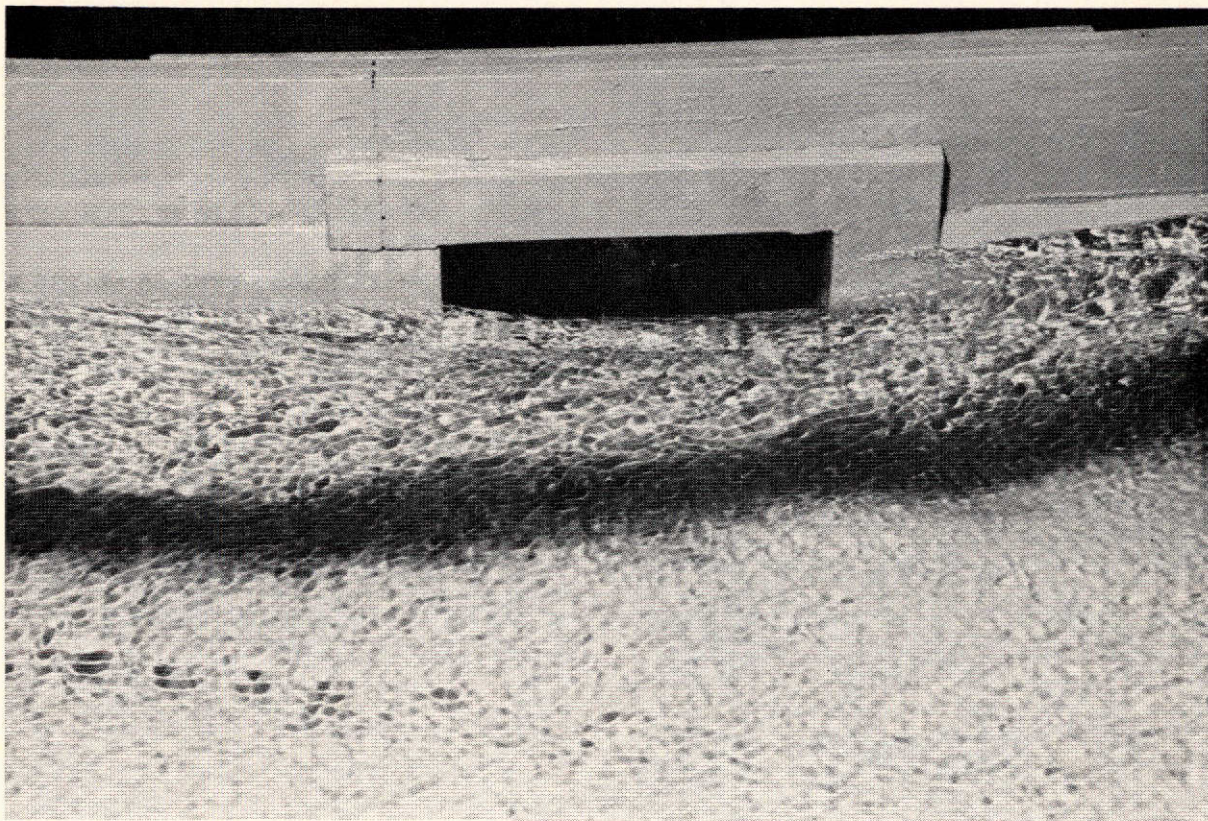
The proposed methodology attempts to reconcile rainfall frequency relations with flood frequency relations via the introduction of "frequency-equivalent" rainfall-runoff curves. Basin storage and loss function effects are evaluated separately. Basic concepts of established hydrograph theory are retained in the analysis. The method can be applied to operational problems associated with specific storms as well as to frequency relations.

WATER QUALITY CONTROL VERSUS RESIDENTIAL RESERVOIR DEVELOPMENT

Sherman M. Wyman, Louis E. Striegel, Nicholas J. Elliot, Conall D. O'Leary

Kansas Water Resources Research Institute

This study is focused on political and administrative problems facing local governments responsible for controlling the impact of residential development on water quality in the Perry and Clinton reservoir areas in Kansas. Significant constraints on both the local governments and other parties involved in development are being identified and described. These descriptions are being based on: 1) attitude surveys of developers, small parcel owners, and state and local govern-



Gutter flow (from left to right) with curb opening showing disturbance of free surface; dyed stream line shows deflection of water toward the inlet.

ment officials regarding improvement costs, tax burdens, and changes in governmental policies, structures, and powers; 2) a review of the limitations existent in current statutes; and 3) a comparative study to identify governmental patterns and policies which have been effective at other Midwest reservoirs.

In addition to a final technical report, a pamphlet is being prepared containing information for potential buyers. It will be designed for use by developers, governmental officials, and interested citizens.

HIGHWAY STORM DRAINS

John S. McNow and Chi-Hsiung Tai
Kansas Water Resources Research Institute

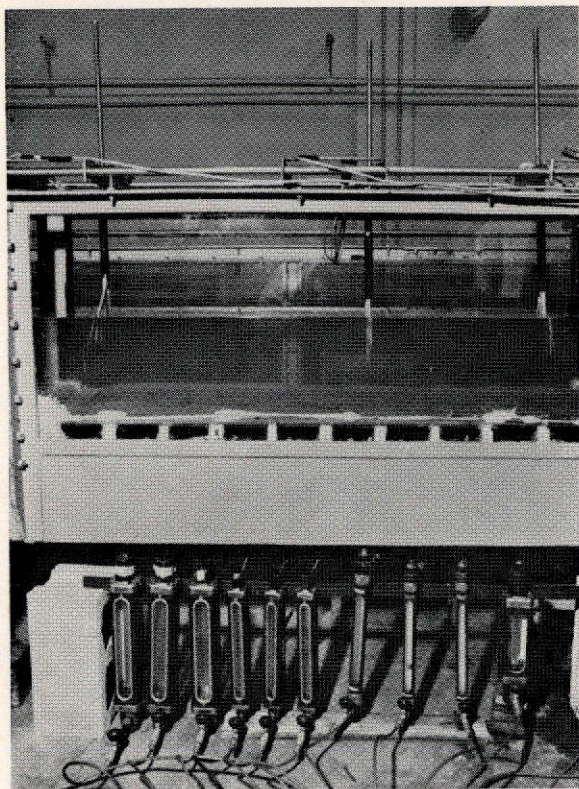
As one component in balanced storm drainage, the inlet to a storm sewer presents difficult problems. Such diverse factors as safety, patterns of gutter flow, type of flow

diversion, construction methods and economics all enter into design practice. Several of these factors were included in the design of a laboratory investigation of a model inlet based on practice in the Kansas State Highway Commission. Measurements include distribution of flow in the gutter, proportion of flow in gutter captured by the inlet for various slopes and discharges, and the effect of design modifications. Both better design information and improved designs are being obtained from the study.

DISPOSAL OF HEATED WATER THROUGH GROUND WATER SYSTEMS

G. P. Willhite, F. Simonpietri, and Jay Stoker
Kansas Water Resources Research Institute

This study concerns the technical and economic feasibility of using a ground water system, hydraulically connected to a larger body



Section of the flume where hot water enters the bottom of the stream flow through a sand bed.

of water, as a means of introducing waste heat into the larger body. In the proposed process, hot water would be injected into the ground water system through wells entering the larger body at numerous points along the sides and bottom. Some of the heat would be dissipated by conduction to the underlying and overlying strata; the remainder would be dispersed in the larger body of water as the heated water rises due to density differences.

Research activities have been separated into two parts: 1) numerical simulation of fluid flow and heat transfer in the ground water system; and 2) a study of mixing in a scaled model of the Kansas River.

A computer program has been written describing the three dimensional flow of water in an aquifer underlying the Kansas River. A second program is under development which will estimate the temperature distributions in the aquifer when hot water is injected through a well. These programs, when coupled, will

yield estimates of temperature and flow rate at which the waste heat enters the river.

Scaled mixing studies of the hot water in the Kansas River are underway in the 1-foot flume in the Civil Engineering Laboratory. Hot water enters the flume bottom through a sand box mounted in the flume. Temperatures are monitored at 30 points located upstream and downstream from the region of injection. Interpretation of these profiles indicates how well the hot water mixes as it rises through the colder river water.

WEATHER UTILIZATION ASPECTS OF WEATHER MODIFICATION AS APPLIED TO KANSAS

Robert L. Smith, M. Bansal, I-Lung Cheng
Kansas Water Resources Research Institute

Surprisingly little attention has been directed toward appraisal of the water supply aspects, as contrasted to precipitation augmentation aspects of weather modification programs. This project utilizes a digital model of the land phase of the hydrologic cycle to make such an appraisal. Detailed computer studies were conducted on seven basins in Kansas. Results of similar computer studies as reported by other investigators for four California basins, one Kentucky basin, one Vermont basin, and one New South Wales basin were also appraised. Supplemental hydrologic relations utilized in development of predictive equations were based on information from approximately 200 basins extending from Kansas to Puerto Rico.

A procedure for predicting the percentage gain in average annual runoff to be realized under conditions of uniformly augmented precipitation was developed by numerical analysis of the available hydrologic parameters. This predictive equation appears to have widespread application inasmuch as the results of the computer simulations from all 14 basins provide comparable results.

The studies indicate that in Kansas, under conditions of uniform augmentation, the percentage increase in average streamflow would be approximately four times the percentage increase in average precipitation. However,

this potential increase has to be discounted approximately one-half when allowance is made for practical operating constraints—e.g., precipitation augmentation would be prohibited during incipient flood periods or during harvest periods. Except for benefits to dry land agriculture, the beneficial water supply aspects of weather modification in Kansas will be limited primarily to increased yield of surface impoundments. The studies indicate the percentage gain in gross sustaining reservoir yields would approximate the percentage gain in precipitation.

Preliminary exploration of the effects on stream yields indicates randomness in the augmentation process will not pose significant problems in appraising the potential water supply aspects of the program.

Project results have direct application to long-range water planning studies, both in Kansas and elsewhere in the nation.

USE OF LIME-SODA ASH SLUDGE FOR THE TREATMENT OF MUNICIPAL WASTEWATER

Walter J. O'Brien and James W. Moore
Kansas Water Resources Research Institute

The development of new approaches for the disposal of water softening sludge has assumed increased importance within the past several years because of the desire to improve water quality in streams and lakes. The use of water softening sludge to treat wastewater would permit significant financial savings to a municipality.

Pilot plant investigations being conducted at the present time indicate 40 to 50 percent of the phosphorous, 90 to 95 percent of the suspended solids, and 50 to 60 percent of the BOD present in the influent to the wastewater treatment plant at Lawrence, Kansas, can be removed using a mixing chamber followed by sedimentation. A portion of the sludge removed from the sedimentation basin is recycled back to the mixing chamber.

Approximately 500 milligrams (dry weight) of water softening sludge is added to each liter of wastewater. The concentration of solids in the mixing chamber is being

varied over the 1000 to 2500 mg/l range to determine the effect this parameter will have on treatment efficiency.

The waste sludge produced by the process is not offensive and can be readily dewatered by vacuum filtration. After heat drying and grinding it may be useful as agricultural lime.

The mechanism for phosphate removal appears to be adsorption on the surface of the calcium carbonate precipitate present in the water softening sludge. An investigation is being conducted at the present time to test this hypothesis.

THE DEVELOPMENT AND FIELD TESTING OF A BASIN HYDROLOGY SIMULATOR

D. W. Green, E. C. Pogge, J. Halepaska, R. Knapp, D. Richards, B. Schorn, and M. C. Huang

Kansas Water Resources Research Institute

Research is underway to develop a digital computer model which will simulate the hydrology of a stream basin including both surface water and ground water phases. Input to the model will include precipitation, climatic conditions, boundary and initial conditions, and basin constants. Provision will be made for modeling withdrawals from both ground water and surface waters for consumptive use. The output will include streamflow hydrographs at selected points, ground-water levels, and ground-water recharge and discharge from the basin.

The model will be structured such that it can be applied to any basin with a minimum of modification, and will be sufficiently flexible to handle a case where the principal interest is either in surface water or ground water.

It is planned to test the model by application to a basin where both surface and ground water factors are important and interdependent. The test will consist of a comparison of calculated performance with observed historic records of stream flows and aquifer levels. Also, the use of the model as a management tool in optimizing the future development and operation of a basin will be demonstrated.

LONGITUDINAL DISPERSION AND REAERATION IN NATURAL STREAMS

Yun-Sheng Yu and M. K. Bansal

Kansas Water Resources Research Institute

The previous work by the investigators on the longitudinal dispersion of the Lower Kansas River Basin has been extended to include the dispersion and reaeration in other natural streams. The results show that the dimensionless dispersion parameters and the Reynolds number of the flow are linearly related on a log-log plot. An analysis of the available data on reaeration coefficients from different reaches of natural streams shows that a similar relation exists between the dimensionless reaeration parameter and the Reynolds number.

NUMERICAL MODELING OF UNSATURATED GROUND-WATER FLOW INCLUDING EFFECTS OF EVAPOTRANSPIRATION

D. W. Green, H. Dabiri, J. D. Khare, and J. Collins

Kansas Water Resources Research Institute

A mathematical model describing two-phase flow in porous media has been developed. The model, which consists of describing differential equations and an algorithm for their numerical solution on a digital computer, is applicable to the investigation of one-dimensional, vertical ground water movement in unsaturated soils, considering losses due to evaporation and transpiration (evapotranspiration).

The second order, non-linear, partial differential equations describing water-air flow through porous media have been extended to include water losses due to unsteady-state evapotranspiration. The basis of the extension is an analogy to Ohm's law. The water transport in the soil-atmosphere or the soil-plant-atmosphere system has been considered to take place due to the existence of successively decreasing driving-force potentials from the soil to the atmosphere.

The applicability of the model is being evaluated by comparison of computed results

with experimental field data taken by the United States Geological Survey. These data were obtained using a neutron logging device to measure soil moisture, as a function of depth and time, in a sand dune area of South-western Kansas. Both transpiration and evaporation were active in the test area. Good agreement between calculated results and the experimental data has been found in comparisons to date.

AN ECONOMIC MODEL OF AN AREA'S RESPONSE TO DEPLETION OF ITS WATER RESOURCE

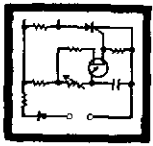
R. W. Ruppert, G. S. Clausen, J. H. Hoag

Kansas Water Resources Research Institute

In Kansas and elsewhere in the semi-arid west, irrigation development has led many areas to depend upon the mining of local groundwater for considerable proportions of their income. These areas can be viewed as facing three alternatives as groundwater depletion takes place: 1) by developing more water through alternative sources of supply such as improved natural recharge, importation and artificial recharge, and waste water reuse; 2) by transferring water use to less-consumptive, higher-yield applications such as high-yield crops or manufacturing processes; 3) by incurring reductions in population and income because of migration. The purpose of this research is to develop an economic model for determining the appropriate combination of the alternatives for an area to use and the way in which that combination should be varied over time as the depletion continues.

After the basic aggregative model has been developed and analyzed, it is planned to disaggregate the model into three categories of use: agricultural, industrial, and municipal. This disaggregated model will be analyzed to see how the pattern of water allocation between the three uses varies as depletion takes place.

The basic mathematical method used is optimal control theory. A portion of the research effort will be directed toward assessing the potential application of the model to case studies in Kansas.



ELECTRICAL ENGINEERING

Arthur Breipohl, Chairman

The staff of the Electrical Engineering Department are associated with a wide variety of research projects which represent the breadth of research in electrical engineering. By far, the largest effort in terms of faculty time is devoted to the area of Remote Sensing which is reported separately in this document. However, we also have research projects in the classical electrical engineering fields of communications, semiconductors, computers, control systems, and circuits. In addition, we have research projects in fields related to electrical engineering including bioengineering, pattern recognition, human factors, and studies of large non-engineering systems.

There are three primary purposes for our research: (1) to increase the available store of knowledge; (2) to find or invent new solutions for problems facing humanity; and (3) to educate students (both graduate and undergraduate) and faculty. The research problems chosen by the staff and described herein represent, in varying degrees, all of the above motivations.

A COMMUNICATIONS MEASUREMENT STUDY

A. Breipohl, H. Doemland, J. Holtzman,
R. Klein, J. Rupf
Richards-Gebaur Air Force Base

The Department of Electrical Engineering is studying the communications systems that are operated and maintained by Richards-Gebaur Air Force Base. This study is designed to understand the measurements presently being made, to formulate a model or models of the communication system which

demonstrates the effects of measurements and, eventually, to recommend improved measurement techniques. The preliminary study is concentrating on the measurements and models of measurements on the communication link between Richards-Gebaur and Harrisonville, Missouri.

The study seeks to identify some basic parameters of the communication system which are important in determining performance, and to determine the ability of the measurement system to correctly estimate these basic parameters.

INFLUENCE OF INCLINATION ANGLES FOR ANTENNAS BURIED IN ARCTIC TERRAIN ON SPACE WAVE RADIATION

Albert W. Biggs
Naval Ordnance Laboratory

Space wave radiation fields for an inclined electric dipole antenna in Arctic and Antarctic terrain were formulated with the results from superposition of fields for horizontal and vertical dipoles. Boundary conditions and the Fourier-Bessel transforms were applied to the wave equations in each layer of the multi-layer media used as the terrain model. Integral expressions were obtained in closed form in terms of the media parameters. Homogeneous and stratified media, with ice above sea water or soil, were investigated. The inclination angles for optimum (maximum) space wave fields in a fixed polar angle θ were obtained for both types of terrain, and patterns of the radiation fields determined for several terrain conditions and inclination angles.

TERRAIN INFLUENCES ON EFFECTIVE GROUND CONDUCTIVITY

Albert W. Biggs

Naval Ordnance Laboratory

Measurements of the ground wave field intensity were made along radial paths from a low-frequency transmitter in Rapid City, South Dakota. Ground wave attenuation curves for different conductivities were compared with the measured data. Millington's mixed path theory for path segments with different conductivities was then applied to obtain a ground conductivity map. Effects of topological features such as hills, ridges, and rivers, and variations in ground moisture and temperature were investigated. Hills and ridges along each radial path indicated the influences of terrain irregularities. The conductivity variations were found to affect radio station coverage for low-frequency range stations.

BLOOD PRESSURE REGULATION BY DIFFERENTIAL ADJUSTMENT OF CARDIAC OUTPUT AND VASCULAR RESISTANCE

J. W. Trank and H. W. Shirer

Kansas Heart Association

Arterial blood pressure is regulated by a closed feedback loop. Stretch receptors in the walls of central arteries, particularly those of the carotid sinus, provide nerve signals proportional to pressure. These nerve signals are processed in centers in the brain stem from which further nerve traffic is sent to the heart and the terminal arterioles of the vascular system. As a consequence of the feedback loop, a fall in arterial pressure generally produces an increased cardiac output and an increased arteriole constriction leading to a restoration of pressure. An initial rise in arterial pressure produces the opposite effects, again restoring the pressure. Present knowledge, however, does not explain differential adjustment of heart function and arteriole constriction. Since arterial pressure is the product of cardiac output and vascular resistance, at any moment the pressure may deviate from the set point because either cardiac output or vascular resistance is inappropriate. Optimum physiological adjustments would seem to demand appropriate differential effector adjustment.

It is hypothesized that information as to the relative states of heart action and vascular resistance is contained in the carotid sinus stretch receptors or "baroreceptor" nerve traffic. It is known that the baroreceptors are both proportional and rate sensitive to pressure. The arterial pressure waveform is characterized by a steep rise resulting from the rapid injection of blood by the heart stroke, followed by an exponential-like decay as blood runs out of the distended arteries through the vascular resistance established by the arterioles. Thus, the baroreceptor nerve traffic pattern, relative to the heart cycle phase, will show relatively high early traffic when heart stroke vigor is high and runoff fast through a low resistance and higher late traffic with less active heart action and slow run off through a high vascular resistance. It is proposed that the appropriate adjustments of heart and arteriole states is made from a comparison in the brain centers of the phase of baroreceptor nerve traffic to other nerve indices of the phase of the heart cycle.

Anesthetized experimental animals are studied by recording heart action from a magnetic flowmeter placed on the main outlet artery, along with arterial pressure from a catheterized central artery via an electrical transducer, and vascular resistance from an analog divider taking the ratio of pressure to flow signals. The relative responses of the heart and vascular system to phased stimuli supplied by electrodes to the carotid sinus wall will determine the differential sensitivity and relative loop responses of the two systems. These results will add further to our understanding of cardiovascular control and possibly contribute to our knowledge about such disease states as high blood pressure.

REPTILIAN CARDIOVASCULAR REGULATION

J. W. Trank, H. W. Shirer, G. A. Stephens

Kaw Valley Heart Association

Regulation of blood circulation is carried out largely by the autonomic nervous system. This nervous system has its important signal processing centers in the spinal cord and lower brain. In advanced vertebrates, such as mam-

mals, the autonomic centers are modulated by higher centers in the neocortex of the more complex brain. To study the basic processes of cardiovascular regulation the higher centers must be eliminated from function by anesthesia. Unfortunately, such anesthesia also affects the primary, autonomic centers as well as functional components within the heart and blood vessels. By studying a more primitive vertebrate, such as a reptile, the basic autonomic control of the circulation is at hand with little influence from other centers. Development of techniques that permit humane study of the unanesthetized reptile allow unambiguous analysis of basic cardiovascular regulation.

Turtles are prepared by providing a chronic hydraulic connection to a central artery. This port provides access for direct monitoring of central arterial blood pressure as well as a convenient means for the administration of drugs and physical challenges. Arterial pressure is an important regulated parameter in itself, but also contains information in its waveform as to heart action and the activity of the terminal arterioles that provide most of the resistive load placed on the heart.

The initial phase of the study is the determination of the characteristics of arterial pressure regulation in restrained but otherwise normal animals in a controlled laboratory environment. This will provide a basis for comparison, in later studies, to arterial pressure patterns in unrestrained animals in their natural habitat monitored by radio telemetry.

TEMPERATURE REGULATION IN FREE-RANGING OPOSSUMS

H. W. Shirer, D. D. Pippitt, and J. D. Pauley
NIH Biomedical Sciences Support Grant

Behavioral and physiological strategies for temperature regulation are being compared in the native opossum, a primitive marsupial mammal, in its natural environment. An implanted, two-channel pulse modulated telemetry transmitter provides data on core temperature and heart rate. Data is acquired either manually, by tracking with a portable direction-finding receiver and digital readout equipment, or on a central data storage sys-

tem via transponding radio repeaters. All telemetry system components were developed in the Bioinstrumentation Laboratory, jointly sponsored by the Department of Electrical Engineering and the Department of Physiology and Cell Biology.

Animal heat production is estimated from heart rate and a factor determined from direct oxygen consumption measurements made prior to release of each individual. The ratio of core-environment temperature gradient to heat production provides a measure of heat conservation thermal resistance. Behavior is monitored by remote tracking of the position and movements of the animal from the telemetry signal.

In contrast to laboratory studies of restrained animals, these free-ranging studies allow the role of behavior to be related to physiological adjustments of heat production and heat conservation for various environmental conditions. The studies are aimed in part at determining organism management of energy resources and in part at understanding biological control mechanisms. In animals, behavior shows much of the characteristics of open sequence control while physiological adjustments are largely feedback mechanisms.

RADIO TRACKING OF WILD ANIMALS IN THEIR NATURAL HABITAT

H. S. Fitch, R. Hoffman, H. W. Shirer, L. A. Gold, R. L. Lattis, C. B. Rideout, and R. C. Walner
NIH Biomedical Sciences Support Grant

Movements of animals about their home range are being followed with the aid of attached radio transmitters. Once the unit is placed on or within the animal, it can be located at will with negligible disturbance to its natural behavior. Location of the transmitter and host animal is carried out with a portable direction-finding receiver system. Animals are identified by their individual, crystal-controlled transmitting frequencies in the 27 MHz frequency range. The present studies are extensions from techniques developed for past studies of box turtles, eastern Kansas snakes, opossums, racoons, skunks, and marmots.



Radio tracking of an animal in its natural habitat.

Snakes in southwestern Kansas are being tracked with transmitters fed to them. The silicone rubber-covered oval units of approximately prey size are retained in the snake's stomach for several weeks and apparently produce little interference with further feeding and movement. Transmission distances up to 100 yards and a useful life of about one month permit simple location of otherwise secretive animals.

Soft-shelled turtles living in the Lawrence-Eudora stretch of the Kaw River are being followed from transmitters cemented to their upper shell. Since these animals spend most of their time hidden in the muddy water, their movements are largely unknown. Fresh water does not interfere with propagation sufficiently to prevent location from distances up to at least one quarter mile. Greater reception range is being aided by use of a new, low-noise receiver of high tuning accuracy.

Mountain goat movements in the Montana Rocky Mountains are being determined from transmitters attached as rugged collars, firmly fastened around the neck. The larger size, higher elevation from ground, and larger batteries permitted by this large animal provide a detection range of up to two miles and transmitter life of several months.

Home range studies of wild animals provide an important link in understanding organism-to-organism and organism-environment interaction as well as the natural history of many infectious diseases for which they may be a prime host or significant vector.

MAGNETIC TAPE RECORDING OF EKG AND COMMENTARY FROM AMBULATORY PATIENTS

A. C. Mitchell, H. W. Shirer, and L. E. Herzmark
University of Kansas

It has been generally found that graded exercise in the form of walking is beneficial to patients who have recovered from heart attacks. Some patients undergo a prescribed regime of increasingly vigorous walks without any untoward symptoms while others experience some transient chest pain, shortness of breath, or fatigue. Understanding of the basic nature of cardiac infarct healing as well as improved convalescent management would result if electrocardiograms, recorded simultaneously with the patient's commentary, could be obtained during the prescribed exercise.

To achieve the needed exercise monitoring, the following program of study has begun. A common, battery-operated, cassette magnetic tape recorder, weighing less than five pounds, is carried by the patient and allows up to one hour of continuous recording. Voice commentary and the electrocardiogram are frequency multiplexed on the single recording channel. Voice commentary is limited to a band of 300 to 3000 Hz. The EKG signal is recorded as a frequency modulated subcarrier in the 6 kHz region limited to 40% deviation. These preconditioned signals are linearly added and used as recorder input in lieu of the standard microphone. On playback, the audio and EKG signals are separated by filters and presented on a speaker and oscilloscope, respectively.

It is expected that development of the monitoring system as a low-cost accessory to conventional portable magnetic tape recorders will make available an important tool to physicians for research and improved patient management.

A SENSITIVITY STUDY OF THE VARIATION OF
MICROWAVE APPARENT TEMPERATURE AS A
FUNCTION OF THE SURFACE AND ATMOSPHERIC
PARAMETERS

S. Wu and A. K. Fung
NASA
(See Remote Sensing)

CALCULATION OF MICROWAVE ATMOSPHERIC
TRANSMITTANCE UNDER VARIOUS
WEATHER CONDITIONS

S. Wu and A. K. Fung
NASA
(See Remote Sensing)

THE METEOROLOGICAL EFFECTS ON MICROWAVE
APPARENT TEMPERATURES LOOKING DOWNWARD
OVER A SMOOTH SEA

S. Wu, A. K. Fung, F. T. Ulaby, and R. K. Moore
NASA
(See Remote Sensing)

THE EXACT NUMERICAL SOLUTION OF RADIATIVE
TRANSFER PROBLEMS IN THE PRESENCE OF RAIN

A. K. Fung and S. Wu
NASA
(See Remote Sensing)

THE EXTINCTION COEFFICIENT, THE SCATTERING
COEFFICIENT AND THE ALBEDO OF PRECIPITATION

A. K. Fung and S. Wu
NASA
(See Remote Sensing)

ON BACKSCATTERING FROM TWO-SCALE
ROUGH SURFACES

A. K. Fung and H. L. Chan
NASA
(See Remote Sensing)

ON THE INTEGRAL FOR BACKSCATTERING FROM
A RANDOMLY ROUGH SURFACE

A. K. Fung and H. L. Chan
NASA
(See Remote Sensing)

COMPARISON OF THE SCATTERING CHARACTERISTICS
OF DIFFERENT COMPOSITE ROUGH
SURFACE MODELS

A. K. Fung and H. L. Chan
NASA
(See Remote Sensing)

BACKSCATTERING FROM ROUGH SURFACES NEAR
VERTICAL INCIDENCE

A. K. Fung and H. L. Chan
NASA
(See Remote Sensing)

SIGNAL RECORDS IN BACKSCATTERING STUDIES

A. Zachs and A. K. Fung
NSF
(See Remote Sensing)

MULTIFREQUENCY MEASUREMENTS OF
BACKSCATTERED ENERGY FROM A THIN LOSSY
IRREGULAR LAYER

A. K. Fung and A. Leovaris
NSF
(See Remote Sensing)

RADAR AGRICULTURE MEASUREMENTS WITH
SCATTEROMETERS

G. A. Bradley and J. C. Holtzman
NASA-MSR and THEMIS
(See Remote Sensing)

TOWARD RADSCAT MEASUREMENTS OVER THE SEA

J. P. Claassen and R. K. Moore
NASA
(See Remote Sensing)

RADAR SCATTEROMETER OCEAN MEASUREMENTS

R. K. Moore, G. A. Bradley, and J. C. Holtzman
NASA-MSR
(See Remote Sensing)

RADAR SEA ICE MEASUREMENTS

G. A. Bradley, J. C. Holtzman, R. K. Moore,
and A. W. Biggs
NASA-MSR
(See Remote Sensing)

VOLUME SCATTERING FROM SEA ICE AND
GLACIER SNOW

Albert W. Biggs
Naval Ordnance Laboratory
(See Remote Sensing)

SEA ICE DISCRIMINATION WITH
RADAR SCATTEROMETERS

A. W. Biggs, R. M. Haralick, and R. K. Moore
Naval Ordnance Laboratory
(See Remote Sensing)

SCATTEROMETRY TECHNIQUES FOR SENSING
ARCTIC SEA ICE THICKNESS

A. W. Biggs, D. Fayman, and R. K. Moore
U.S. Naval Ordnance Laboratory
(See Remote Sensing)

A COMPLEMENTARY MICROWAVE SYSTEM FOR
BACKSCATTERING MEASUREMENTS

A. K. Fung and A. Zachs
NSF
(See Remote Sensing)

WIND WAVE EXCITATION OVER GRAVITY WAVES—
A TWO-SCALE SEA SIMULATOR FOR
SCATTERING EXPERIMENTS

A. Zachs and R. K. Moore
Naval Oceanographic Office and NASA
(See Remote Sensing)

DESIGN AND CONSTRUCTION OF A
RADAR SCATTEROMETER

Albert Biggs, David Fayman, and Robert Matreci
U.S. Naval Ordnance Laboratory
(See Remote Sensing)

THE CONSTRUCTION OF A COMPOSITE ROUGH
TARGET FOR BACKSCATTERING EXPERIMENTS
A. K. Fung and A. Zachs
NSF
(See Remote Sensing)

CW MODIFICATION OF THE MICROWAVE
BROADBAND SPECTROMETER
R. K. Moore and Ronald D. Moe
NASA and THEMIS
(See Remote Sensing)

A 4-TO-8 GHz RADAR SPECTROMETER AND
BROAD BANDWIDTH IMAGER
W. P. Waite, R. K. Moore and Ron Moe
NASA and THEMIS
(See Remote Sensing)

SPECTRAL RESPONSE MEASUREMENTS IN THE
MICROWAVE REGION
W. P. Waite, R. D. Moe, R. K. Moore and
H. Razaghi-Khamsi
NASA and THEMIS
(See Remote Sensing)

THE MICROWAVE EMISSION FROM THE SEA
A. K. Fung and S. Wu
NASA
(See Remote Sensing)

GROUND WAVE PROPAGATION OVER
ARCTIC SEA ICE
Albert W. Biggs
Naval Ordnance Laboratory
(See Remote Sensing)

EFFECT OF ANGULAR VARIATION ON TERRAIN
SPECTRAL REFLECTIVITY
D. D. Egbert and F. T. Ulaby
Department of Defense (THEMIS) and NASA
(See Remote Sensing)

BROAD SPECTRUM IMAGING RADAR
W. P. Waite and R. K. Moore
NASA and THEMIS
(See Remote Sensing)

PANCHROMATIC ILLUMINATION FOR RADAR—
ACOUSTIC SIMULATION OF PANCHROMATIC RADAR
G. C. Thomann and R. K. Moore
NASA and THEMIS
(See Remote Sensing)

EXTRACTING QUANTITATIVE DATA FROM
PHOTOGRAPHICALLY RECORDED RADAR IMAGERY
J. Holtzman, F. Dickey, and T. James
NASA
(See Remote Sensing)

COLLECTION OF SCATTEROMETER DATA OVER
THULE, GREENLAND, AND ALERT, CANADA
David Fayman and Robert Matreci
U.S. Naval Ordnance Laboratory
(See Remote Sensing)

RADAR IMAGE QUALITY
J. Holtzman and F. Dickey
NASA
(See Remote Sensing)

RADAR HOLOGRAM PROCESSOR
J. Holtzman and F. Dickey
NASA
(See Remote Sensing)

DIGITAL PROCESSING OF SYNTHETIC
APERTURE RADAR
Ralph Gerchberg, R. K. Moore, Fred Dickey,
J. Holtzman
NASA
(See Remote Sensing)

RADAR SYSTEM ANALYSIS
J. Holtzman and F. Dickey
NASA
(See Remote Sensing)

RADAR SCATTEROMETER SYSTEM ANALYSIS
G. A. Bradley, J. C. Holtzman, R. K. Moore, and
J. Young
NASA—MSC
(See Remote Sensing)

SKYLAB—S193 RADSCAT DEVELOPMENT
R. K. Moore, W. E. Spencer, Walter Hanley, and
Arun Sobti
NASA
(See Remote Sensing)

A COMPARISON OF METHODS OF ESTIMATING THE
MEAN SQUARED SIGNAL
J. P. Claassen
NASA
(See Remote Sensing)

MULTISPECTRAL HASSELBLAD CAMERA CLUSTER
D. D. Egbert, J. C. Barr, and R. K. Moore
NASA
(See Remote Sensing)

AN AUTOMATED IMAGE PROCESSING SYSTEM—
IDECS (IMAGE DISCRIMINATION, ENHANCEMENT,
AND COMBINATION SYSTEM)
R. K. Moore, G. L. Kelly, R. M. Haralick, and
P. Anderson
NASA, U.S. Army, THEMIS
(See Remote Sensing)

IDECS-PDP 15/20 COMPUTER INTERFACE
P. N. Anderson
NASA and U.S. Army
(See Remote Sensing)

COMPUTER CONTROLLED SIGNATURE SELECTOR
T. Polcyn and P. Anderson
U.S. Army
(See Remote Sensing)

IDECS DISC OPERATING PANEL
P. Anderson and J. Lubert
NASA and U.S. Army
(See Remote Sensing)

IDECS FLYING-SPOT SCANNERS
P. Anderson, T. Polcyn and J. Barr
NASA and U.S. Army
(See Remote Sensing)

KANDIDATS

R. M. Haralick, G. Gunnels, G. Reynolds, and
M. Afarani
NASA and THEMIS
(See Remote Sensing)

ADAPTIVE PATTERN RECOGNITION SYSTEM
R. M. Haralick and I. Dinstein
NASA
(See Remote Sensing)

MULTI IMAGE CLUSTER ANALYSIS
R. M. Haralick and I. Dinstein
THEMIS and USGS
(See Remote Sensing)

TEXTURE TONE STUDY
R. M. Haralick
U.S. Army Engineer Topographic Laboratories
(See Remote Sensing)

MAKING PICTURES WITH A DIGITAL COMPUTER
PRINTER
R. M. Haralick
THEMIS
(See Remote Sensing)

FREQUENCY SPECTRAL ANALYSIS OF SLAR
VEGETATION TEXTURES
N. E. Hardy, S. A. Morain, D. D. Egbert and
F. T. Ulaby
NASA
(See Remote Sensing)

OPTICAL DATA PROCESSING FOR SPATIAL
FREQUENCY ANALYSIS
D. D. Egbert and F. T. Ulaby
Department of Defense (THEMIS) and NASA
(See Remote Sensing)

THEMATIC LAND USE MAPPING WITH SPACECRAFT
PHOTOGRAPHY IN THE DALLAS-
FORT WORTH AREA, TEXAS
D. S. Simonett, F. M. Henderson, G. F. Jenks, and
J. R. Ratzlaff
U.S. Geological Survey
(See Remote Sensing)

SNOWFIELD MAPPING USING IMAGING RADAR
H. C. MacDonald and W. P. Waite
NASA and THEMIS
(See Remote Sensing)

SOIL MOISTURE DETECTION WITH IMAGING RADAR
H. C. MacDonald and W. P. Waite
NASA and THEMIS
(See Remote Sensing)

SOIL TEXTURE AND MOISTURE MONITORING
WITH RADAR
S. A. Morain and J. C. Campbell
NASA
(See Remote Sensing)

GEOMORPHIC EVALUATION OF RADAR IMAGERY OF
SOUTHEASTERN PANAMA AND
NORTHWESTERN COLOMBIA
Anthony J. Lewis
U.S. Army
(See Remote Sensing)

VEGETATION MAPPING WITH SIDE-LOOKING
AIRBORNE RADAR: YELLOWSTONE NATIONAL PARK
N. E. Hardy
NASA
(See Remote Sensing)

RADAR GEOLOGY
Louis F. Dellwig, Harold C. MacDonald, Richard
S. Wing, James R. McCauley
NASA, USAETL, U.S. Bureau of Mines
(See Remote Sensing)

RADAR USES FOR NATURAL RESOURCES
INVENTORIES IN ARID ZONES
S. A. Morain
NASA
(See Remote Sensing)

RADAR SENSING IN AGRICULTURE,
A SOCIO-ECONOMIC VIEWPOINT
S. A. Morain, Julian Holtzman, and
Floyd Henderson
NASA
(See Remote Sensing)

MULTIBAND/MULTIDATE PHOTOGRAPH
ENHANCEMENTS FOR AGRICULTURAL LAND USE
John C. Barr (University of Kansas); D. T. Lauer
and G. A. Thorley (University of California
at Berkeley)
NASA and U.S. Army
(See Remote Sensing)

RADAR MONITORING OF AGRICULTURAL LAND USE:
SOME PROBLEMS AND POTENTIALS AT THE
LOCAL LEVEL
F. M. Henderson and S. A. Morain
NASA
(See Remote Sensing)

THE STANDARD FARM: A TIME SEQUENTIAL
DESIGN FOR CONTROLLED PARAMETRIC
RADAR EXPERIMENTS IN AGRICULTURE
J. Holtzman, S. A. Morain, W. O. Lockman, and
P. L. Jackson
NASA
(See Remote Sensing)

AGRICULTURAL CROP DISCRIMINATION WITH COLOR
INFRARED PHOTOGRAPHY: A STUDY IN
DOUGLAS COUNTY, KANSAS
W. G. Brooner
U.S. Geological Survey
(See Remote Sensing)

CROP DISCRIMINATION IN THE LAWRENCE, KANSAS,
AREA BY MEANS OF COLOR, COLOR INFRARED, AND
MULTIBAND PHOTOGRAPHY
A. M. Neumann and D. S. Simonett
U.S. Geological Survey
(See Remote Sensing)

REMOTE SENSING OF TROPICAL AGRICULTURAL
SYSTEMS
C. G. Knight and V. R. Harnapp
NASA
(See Remote Sensing)

OPTIMUM DEPRESSION ANGLES FOR
GEOLOGIC APPLICATION OF RADAR
W. P. Waite and H. C. MacDonald
NASA
(See Remote Sensing)

ENVIRONMENTAL FACTORS INFLUENCING THE
UNIFORMITY OF SPACE PHOTOGRAPHY AS A DATA
BASE FOR URBAN AND AGRICULTURAL LAND USE
MAPPING
D. E. Schwarz
U.S. Geological Survey
(See Remote Sensing)

THE SUSCEPTIBILITY OF ENVIRONMENTS
TO LOW RESOLUTION IMAGING
D. S. Simonett and J. C. Coiner
U.S. Geological Survey
(See Remote Sensing)

IMAGE INTERPRETATION KEYS TO SUPPORT
ANALYSIS OF SLAR IMAGERY
J. C. Coiner and S. A. Morain
NASA
(See Remote Sensing)



MECHANICAL ENGINEERING

Robert R. Gatts, Chairman

Research by students and faculty of the Department of Mechanical Engineering is representative of a wide range of interests including topics associated with the design and construction of machines and mechanical systems as well as with materials properties and fundamental natural phenomena. Specific interests in the department include the field of heat transfer (for example, the phenomenon of transient vaporization), the dynamic behavior of devices and machines (for example, the off-highway riding characteristics of a large vehicle, and the dynamic behavior of space vehicles), the use of analog and digital computers for the analysis and synthesis of mechanism (vector methods in linkage analysis), gas flow and combustion (boundary layer control techniques for low drag land vehicles and emission control in internal combustion engines), mechanical reliability (mechanisms for the accumulation of damage and failure in structural materials, as well as the statistical aspects of mechanical failure prediction and the management of design and development programs).

Departmental facilities at present include an electromechanical shaker system, equipment for the determination of thermodynamic properties of gases, a TR 48 analog computer, a remote terminal to the Honeywell 635 computer in the University Computer Center, general and high speed photographic equipment, an internal combustion laboratory including dynamometers and a single cylinder research engine, optical metallographs, x-ray defraction equipment, equipment for the heat treatment of materials and the determination of general mechanical properties and a loom with 3-dimensional capability. The department also has a wide variety of equipment for machining, forming, welding, and small lot casting of materials.

ATTRITION STUDY

C. J. Baer

University of Kansas

This on-going study of attrition is of all entering engineering students. Each year since 1965 the class of students who enter as freshmen in the School of Engineering have been followed, student by student. Students are observed for seven years, if necessary, until they graduate. Results are tabulated year by year and class by class.

Starting in 1971, this study will include all transfers from junior colleges. Funding is through the Dean's Office from the Endowment Association.

DESIGN OF AN AUTOMATIC DYNAMIC BALANCER FOR A VERTICAL AXIS WASHING MACHINE

James W. Van Kirk and Louis Burmeister
NASA and Whirlpool Corporation

Vibrations due to unbalanced loads in the spin-dry cycle of modern washing machines have long been a problem. A simplified analysis of a particular vertical axis washing machine was made and an automatically controlled dynamic balancer to alleviate the vibrations was designed and developed.

The balancer is a modified Leblanc type utilizing a compartmented water collecting ring with a solenoid controlled water injection system in such a manner as to dynamically balance the original unbalanced load. The design was experimentally tested and was shown to be a feasible solution.

The project was executed by a team of engineering students consisting of one Doctor of Engineering candidate, two Master of Science candidates, and two undergraduates.

POGO RESEARCH

R. R. Gatts, T. H. Wickstrom, H. W. Smith, and
L. C. Burmeister
NASA

Continuing study of the POGO (PrOpulsion Generated Oscillations) phenomena in space vehicles is in progress. The current phase of the program is concerned with the development, construction and testing of relatively simple but representative POGO sensitive systems, mathematical modeling of these systems, and the determination of a strategy for design modification to avoid the POGO phenomena during system operation.

HEAT TRANSFER FROM A PRESSURIZED GAS TO A TEMPERATURE SENSOR

Thomas E. Weast and Louis Burmeister
University of Kansas

A one-dimensional analysis is presented for the transient temperature distribution in a gas whose pressure varies rapidly with time in order to estimate the accuracy at small times of measured rarefaction tube endwall heat flux.

Comparison of predicted rarefaction tube endwall heat flux with data shows satisfactory agreement for small to moderate times. For small times, where data is not available, the predicted endwall heat flux varies with time in a more plausible manner than the discontinuous jump indicated by previous analyses, increasing smoothly from its initial zero value to a maximum with a subsequent decrease.

SIMULATION OF DESIGN AND DEVELOPMENT PROCESSES

R. R. Gatts
University of Kansas

A simulation of the growth of the reliability of a mechanical system during the design and development process is being studied. Special consideration is given to the allocation of resources in terms of design man-hours, prototype build and test programs, and the warranty claims anticipated from customer service.

DESIGN OF A REPRESENTATIVE LIQUID FUEL LAUNCH VEHICLE MODEL TO DEMONSTRATE THE POGO PHENOMENON

Bill G. Tompkins and Louis Burmeister
NASA

PrOpulsion Generated Oscillations are longitudinal oscillations of liquid propellant rockets in flight. The ends of the rocket move against each other in a manner reminiscent of a pogo stick, leading to the characterization of this phenomenon as POGO; it is generally considered to be caused by coupling of the dynamic behavior of the vehicle structure with its propulsion system.

A simplified model representing a launch vehicle was constructed and tested in a vibration testing facility acquired for that purpose to demonstrate that the POGO effect is a phenomenon of generic nature in liquid fueled missiles.

The project was executed by a team of engineering students consisting of one Doctor of Engineering candidate, two Master of Engineering candidates, and ten undergraduates.

THE DEFORMATION OF A VISCOELASTIC HALF SPACE BY A RIGID INDENTER

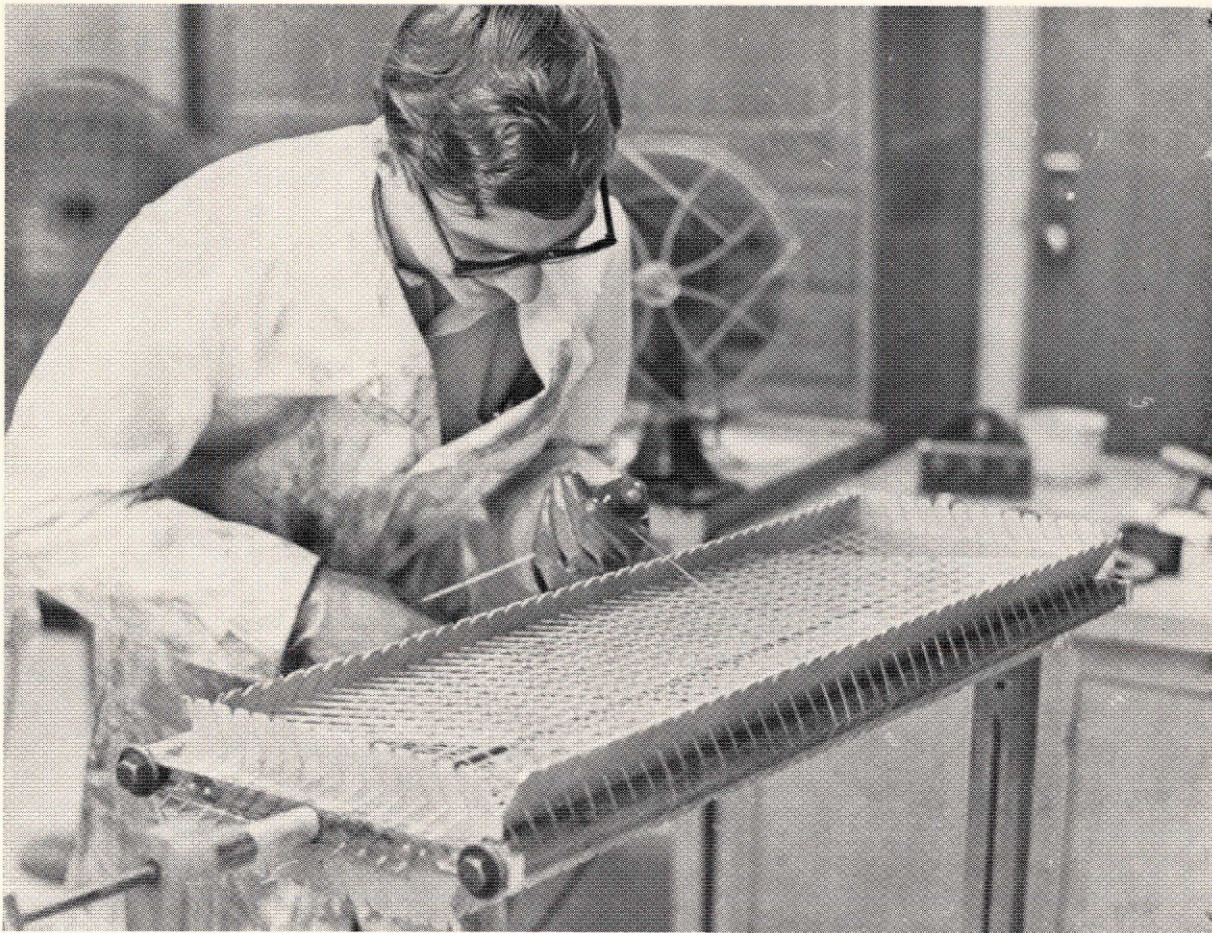
Charles D. Reese and Gerald May
University of Kansas

The primary objective of this research is to experimentally investigate the mechanical behavior of a viscoelastic half space loaded by a rigid indenter and to establish theoretical methods of predicting the results. The results of this investigation would then serve as a basis for conducting optimum valve design studies.

THERMAL FATIGUE PROPERTIES OF CEMENTACIOUS BONDED CERAMICS

M. P. Bauleke and Paul Meiers
University of Kansas

Two phosphate cement bonded ceramic compositions (low glass and high glass content) were formulated. The low glass content, high porosity composition had superior thermal fatigue properties when thermally cycled from RT to 1000°C.



Wrapping tetra-core on a rectangular sloped-wall loom.

FABRICATION AND ANALYSIS OF TETRA-CORE: A LAYERED ANISOTROPIC FIBER COMPOSITE

G. W. Forman and Frank Gordon
NASA

An improved fabrication loom was conceived and tested. The sloped-wall loom developed provides for more positive fiber placement, higher fiber density, and greater flexibility than afforded by the first methods of Tetra-Core fabrication.

Three strength analyses based on the macroscopic properties of Tetra-Core were conducted: netting analysis, layered anisotropic stringer analysis, and layered anisotropic lamina analysis.

An experimental test program was conducted to determine the coefficients of the compliance and stiffness matrices. Four elastic

properties were measured: Young's modulus in the 1 and 2 directions, inplane shear modulus in the 1-2 direction, and Poisson's ratio in the 1-2 direction.

THE USE OF LASER INTERFEROMETRY FOR DETERMINING THE DISTRIBUTION OF FLAWS IN FATIGUE SPECIMENS

R. P. Zerwekh and P. E. Berger
University of Kansas Research Grant

The objective of this work, commencing in academic year 1971-72, is to investigate the feasibility of laser interferometry as a method of determining the distribution of flaws at or near the surfaces of fatigue specimens.

Effects of such flaws on fatigue life will be determined in several metals of engineering interest.

AN INCOMPRESSIBLE FLOW ANALYSIS OF SPRING LOADED GAS COMPRESSOR VALVES

L. C. Burmeister and J. W. Van Kirk
Panhandle Eastern Pipeline, Ball Valve Co., and
School of Engineering

Steady flow data was taken for a variety of compressor valves; both high pressure natural gas and water flow cells were used.

For a single poppet valve tested with water, functional relationships were found relating the resistance flow coefficient to the flow area, and relating the lift, spring constant, maximum deflection, and preload deflection of the poppet to the mass flow rate. The latter relationship was fitted of ninety per cent or less of maximum poppet lift. The relationship only approximated the last ten percent of poppet lift.

The relationships mentioned above and a form of Bernoulli's equation can be used to approximate δP for a simple poppet valve without additional flow testing. Thus, this work gives the analyst a simple tool to approximate the pressure drop of spring-loaded compressor valves from incompressible flow theory.

THE INFLUENCE OF RADIATION ON TRANSIENT VAPORIZATION OF A SATURATED LIQUID AT A CONSTANT TEMPERATURE WALL

Chanchai Limpiyakorn and Louis Burmeister
University of Kansas

The influence of thermal radiation on transient vaporization of a saturated liquid at a constant temperature wall was analytically determined. The effect of gravity was neglected so that the variable property vapor film forming between the plate and the liquid continually increased in thickness as time elapsed. At small times the vapor film is small enough to make conductive heat flow into the liquid-vapor interface much more important than the radiative heat flow from the high temperature plate. The vapor thickness increases as the square root of elapsed time, agreeing with classical results. At large times, radiative heat flow into the liquid-vapor inter-

face predominates over conductive heat flow, and the vapor thickness is directly proportional to time. A similarity solution for this thick film case was obtained and was shown to be in excellent agreement with the numerical solutions comprising the principal method of solution of the describing equations.

KINEMATIC ANALYSIS OF PLANAR LINKAGES USING THE DIGITAL COMPUTER-NUMERICAL DIFFERENTIATION VS. VECTOR MATHEMATICAL TECHNIQUES

R. C. Umholtz
University of Kansas

A comparison of the use of numerical differentiation and vector mathematical techniques for the kinematic analysis of planar four-bar, offset slider crank, and offset quick return mechanisms was made by extensive testing using the GE 635 digital computer and subprograms developed in the study. The numerical differentiation techniques were found to be quite satisfactory for most design purposes.

DEVELOPMENT OF DIGITAL COMPUTER PROGRAMS UTILIZING VECTOR MATHEMATICAL TECHNIQUES FOR THE KINEMATIC ANALYSIS OF MECHANISMS

R. C. Umholtz
University of Kansas Research Grant

Digital computer subroutine subprograms for the analysis of planar linkages have been developed in the course of this investigation.

The first set of subprograms, using algebraic methods, solves for the positional relationship of planar four-bar, offset slider crank, and offset quick return mechanisms. A second set of subprograms uses vector mathematical techniques to determine the angular velocities and accelerations of the various members of these linkages.

FEASIBILITY OF LIQUID NITROGEN EMBRITTLEMENT TO AID RUBBER TIRE FRAGMENTATION BY MECHANICAL IMPACT

Nanuk Grewal and Louis Burmeister
University of Kansas

Embrittlement of rubber tires in a liquid nitrogen bath followed by fragmentation by mechanical impact was experimentally investigated. Whole rubber tires and small specimens from rubber tires were used in this study. The embrittlement resulting from cooling to liquid nitrogen temperatures significantly increased the degree and the ease of fragmentation.

OPTIMIZATION OF ULTRASONIC BONDING PROCESSES

R. C. Umboltz and Frank Bales
Bendix Corp., Kansas City Division

A means of maximizing ultrasonic aluminum wire bond strength to aluminum film

substrates while minimizing scar frequency has been studied. The method developed involves adjusting bonder power and pulse width settings in accordance with the aluminum film texture.

BUCKLING OF ORTHOTROPIC CYLINDRICAL AND CONICAL SANDWICH SHELLS

Charles D. Reese and Kuang-Hsiu Lu
NSF Initiation Grant

The general instability buckling of orthotropic sandwich cylinders and cones subjected to combined axial compression and torsion loading is being investigated. The shell is considered to have clamped supports. The investigation is based on Reissner's version of Love's first-approximation shell theory. A Rayleigh-Ritz assumed mode method of solution is used to reduce the problem to standard eigenvalue form.



INTERDISCIPLINARY RESEARCH

B. G. Barr, Director

The University of Kansas has a strong commitment to interdisciplinary research, as evidenced by the construction of the new Space Technology Laboratories which is used almost exclusively for such investigations.

The National Aeronautics and Space Administration gave impetus to the development of KU's multidisciplinary research in 1962 by an initial grant of \$100,000 to support space research in disciplines throughout the University. KU's Space Science and Technology Committee divided the funds into smaller grants which were then awarded to individual researchers. This same practice has continued each year with subsequent funding by NASA. At the same time, the University responded by broadening the scope of its investigations.

The new Space Technology Laboratories provides a focus for research involving faculty and students from departments throughout the campus. It is a building of flexible design so that its occupancy and the composition of its laboratories may be changed to permit exploration of new directions in multidisciplinary research.

The influence of interdisciplinary thinking is found in practically all research, but many projects began in one discipline and have extended to be influenced by the thinking of others. In all such research the same principle is at work extending the investigation to include every discipline that is relevant to the goals of the research.

Only those projects which are not wholly within an engineering discipline (or separate multidisciplinary section, such as the Remote Sensing Laboratory) are described in this interdisciplinary section.

COMPREHENSIVE GROUND TRUTH STUDIES OF HIGH LEVEL EARTH OBSERVATIONS

F. B. Cross, B. G. Barr, W. W. Hambleton, R. L. McGregor, R. S. Aangeenbrug, and P. S. Humphrey
NASA

Contour mapping and installation of a ground reference system (staked grid) on lands recently acquired by The University of Kansas for comprehensive ecological studies has resulted from project work. Terrestrial and aquatic systems will be investigated in detail and will serve as ground control for high level observation in the northeast Kansas region. The current project provides for a unified system of data acquisition and retrieval by numerous investigators, using both surface and aerial inspection and monitoring. The map and grid are scheduled for completion in 1971-72.

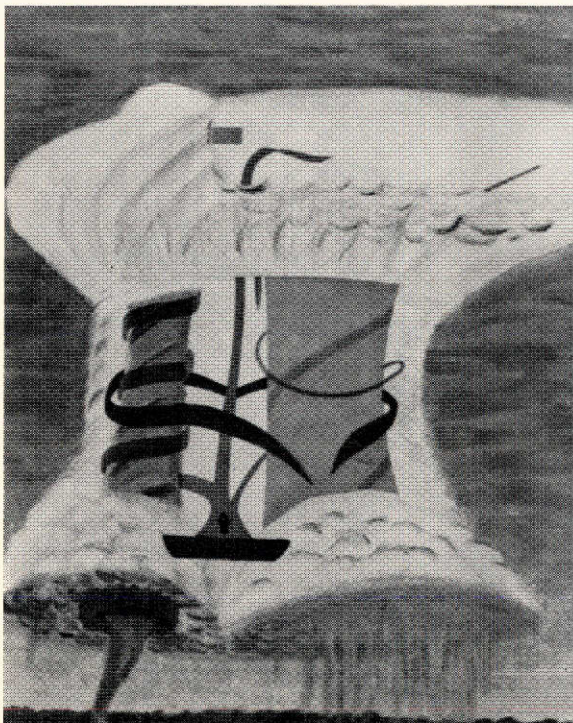
SAFEST LOCATION IN HOUSES IN SEVERE WEATHER

Joe R. Eagleman, Vincent U. Muirhead, Nicholas Willems, R. C. Brown, P. L. Garner, and C. P. Royer
Health, Education and Welfare

The objectives of this research are to: (1) determine the safest location within basements and the first floor of houses without basements during tornadoes; (2) investigate the nature of severe thunderstorms and tornadoes; (3) predict from wind tunnel pressure

tests of model houses probable structural failure modes; (4) using models constructed along current housing construction practices, examine structural failure in wind tunnel tests; and (5) make recommendations for improvement in design and construction of houses to enable them to withstand more severe weather conditions.

Damage investigations have been conducted over the last five years. Statistics have been accumulated on the safest locations in houses damaged by tornadoes. An internal structure of thunderstorms has been proposed which explains various characteristics of tornadoes and thunderstorms. A laboratory model of the tornado vortex has been created with boundary conditions simulating a tornado in the atmosphere. Pressure distribution data have been obtained for thirteen different model house configurations tested in the wind tunnel. Structural components of houses have been tested for strength with nine model houses being destroyed in the wind tunnel testing. The correlation and interaction of these various segments of the research are presently being assembled.



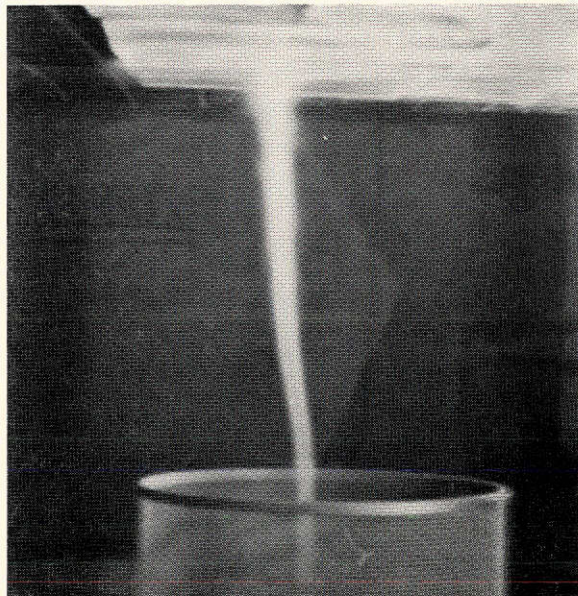
Double Vortex Thunderstorm Model.

THE CUMULATIVE INTERPLANETARY DUST CONCENTRATIONS ON THE LUNAR SURFACE

David B. Beard and Roosevelt Calbert
NASA

Size and spatial distribution of interplanetary dust can be readily inferred from the intensity of light diffracted from interplanetary dust particles at small elongation angles up to about 15 solar radii. This light is observed in the solar corona during solar eclipses. Light scattered by interplanetary dust is also observed as very faint light in the night sky. This light is reflected from small dust particles, but since the reflection calculation depends upon the material composition of the dust and the structure of the surface, both of which are unknown, it is very hard to interpret reliably. Fortunately, the diffracted light in the solar corona is not a critical function of the properties of the dust surface and is much more readily and reliably interpreted. Recent observations of the dust have greatly extended our knowledge of the diffracted solar light.

The most critical uncertainty is in separating the light scattered from dust and the light scattered from electrons. On work supported by the contract, we have been able to make a more reliable estimate of the electron scat-



Laboratory Tornado Vortex.

tered component of light than previously available and have made a very extensive study of the range of parameters of dust size and distribution which fit the observations. We have also been able to make better theoretical estimates than previously available of the minimum distance which the particles can approach the sun before they are completely evaporated.

CHEMICAL REACTIONS INDUCED BY PROTONS IMPINGING UPON THE HIGH ALTITUDE ATMOSPHERE OF THE EARTH

Edward J. Zeller, John D. Zimbrick,
Yash P. Virmani
NASA

The effects of energetic protons on gas targets are under investigation to determine whether significant chemical reactions can occur. The principal objective of the program is to determine whether protons from the Van Allen radiation belts can cause alterations in the properties of the upper atmosphere of the earth. At times of proton aurorae, chemical changes may take place which alter upper atmosphere reflectivity.

The experimental program makes use of a 150 KeV Cockcroft-Walton proton accelerator and a 4 MeV Van de Graaff accelerator. Mass spectrometric methods and electron spin resonance techniques are used to analyze the reaction products.

RADIATION DAMAGE STUDIES IN SOLIDS WITH EPR, ENDOR, AND OTHER TECHNIQUES

Jack W. Culvahouse, Robert J. Friauf, Edward J. Zeller, Y. Hou Chu, and Gerald Holmberg
NASA

The primary emphasis has been the study of proton implantation into KCl and KBr crystals by means of optical absorption measurements. After bombardment with 1 MeV protons the crystals show both the usual F, M, α , and β bands caused by ionization and also two ultraviolet (UV) bands associated with the implanted protons. The position and half width of the most prominent UV band correspond closely to those of the sub-

stitutional hydride ion (U center). The second UV band appears to have the characteristics of the interstitial hydride ion (U_1 center). To verify that these bands are indeed due to implanted protons, we have observed similar UV bands in KCl after deuteron, but not after alpha particle, bombardment. We have also observed the localized mode infrared (IR) absorption of the U center; the shift of wavelength of the IR band on changing from proton to deuteron bombardment gives conclusive evidence that the optical absorption is due to implanted ions. No EPR from atomic hydrogen (U_2 or U_3 centers) is observed except after very long bombardment. By successively slicing off thin layers from the face of the bombarded crystal, we have shown that the implanted layer is about 2 microns thick at a depth of 18 microns, whereas F centers are distributed throughout the 18 micron depth.

In gamma-irradiated KCl:Ag the EPR spectrum shows the presence of Ag^0 and Ag^{2+} centers. ENDOR observations of Ag^0 centers show an additional structure of the high frequency lines from the first shell Cl nuclei, and also give a large number of low frequency lines from both K and Cl nuclei in more distant shells. Similar studies are planned in several other alkali halides containing silver.

REMOTE SENSING AND THE VISUAL ENVIRONMENT

Richard A. Schira
NASA

Investigation into remote sensing and the visual environment as exemplified by the IDECS display system has resulted in a series of observations about high saturation luminous color and its effect on the operator or observer. These observations concern the initial attention response, value judgment and saturation points of the viewer. To further investigate aspects of the color phenomenon, a large series of slides were compiled. Series variations were made of historically known art objects. These slides demonstrate the visual effects of color and its role in breaking down known forms and building new spatial relationships. Films that will add the dimension of movement are now in the working stage as well as study of the possibilities of

cutting this remotely sensed information into real and actual imagery. Other research in this area has been a collaborative effort with Professor R. M. Haralick, Associate Professor of Electrical Engineering, utilizing the computer to develop digital images in color. Work on a computer program for manipulation of visual images is in progress.

Exhibitions (Invitational)-R. A. Schira and R. M. Haralick

- | | |
|----------------|---|
| September 1970 | New Dimensions in Media
Nelson Gallery
Kansas City, Missouri |
| October 1970 | Art for Collectors
Henry Gallery
Seattle, Washington |
| November 1970 | Broadview Community
Church
Colorado Springs, Colorado |
| February 1971 | Thirty Miles of Art
Nelson Gallery
Kansas City, Missouri |
| March 1971 | Lunar Exhibit
Natural History Museum
University of Kansas
Lawrence, Kansas |

Competitive Exhibitions

- | | |
|-------------|--|
| April 1971 | 7th Dulin National Print
and Drawing
Competition
Knoxville, Tennessee |
| August 1971 | 22nd National Exhibition
of Prints
Library of Congress
Washington, D.C. |

CHEMICAL BIOLOGY SEMINAR

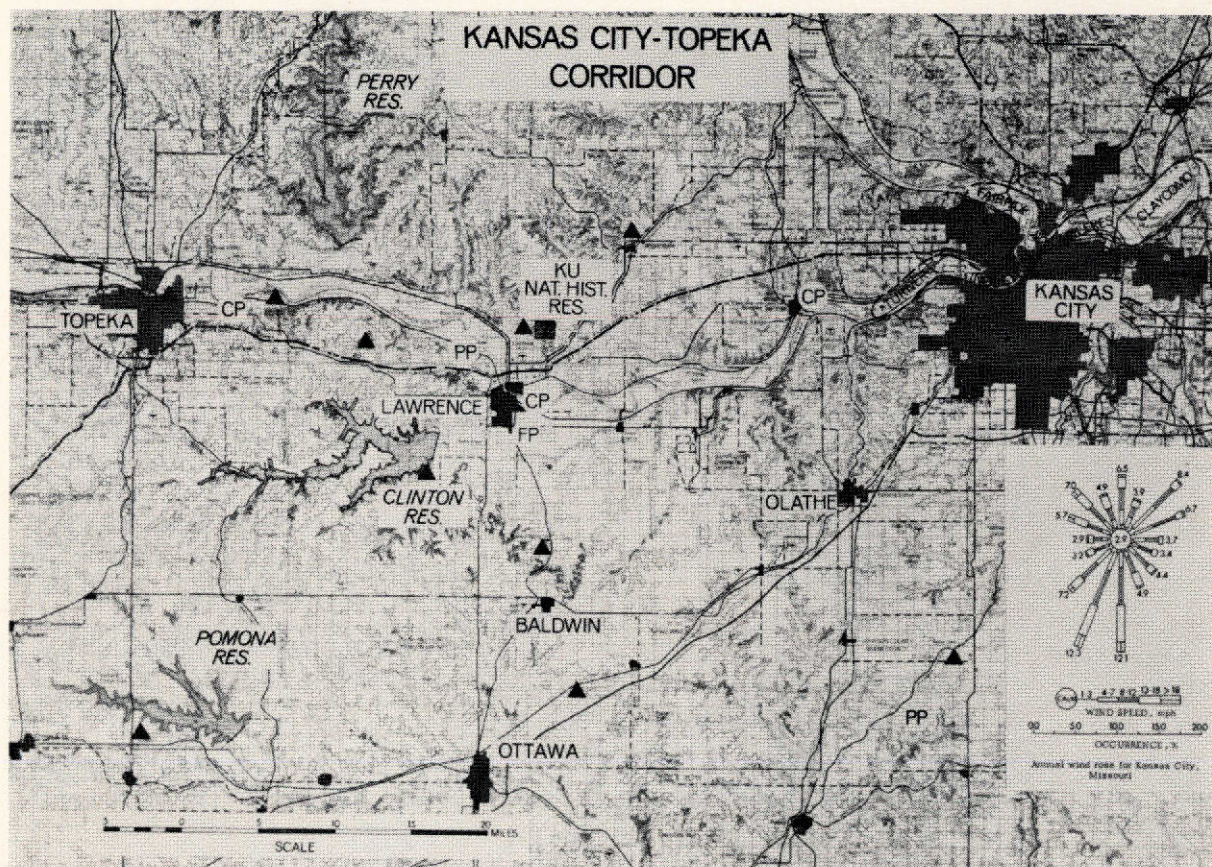
Paul A. Kitos, L. L. Houston and Bruce Molholt
NASA

During the 1970-71 academic year the research seminar series in Chemical Biology hosted eleven distinguished visiting scientists, each of whom consulted privately with local faculty and students in his area of study and delivered a public lecture on the current status of his research. The topics were far ranging—from problems in visualizing single atoms to environmental hazards of radiation. The attendance at the lectures, which included chemists, physicists and biologists of every persuasion, faculty and students, averaged well over fifty, including, in some cases, the closed circuit TV audience at the K.U. medical center.

Since its inception in 1965, the Chemical Biology Seminar Series has served as a meeting ground for research-oriented faculty in diverse fields of science, all of whom in one way or another are interested in biological problems. The program has spawned several on-campus interdisciplinary research activities, the fruits of which are already evident.

The list of speakers in the 1970-71 series is given below:

- DR. RICHARD LOSICK
Biological Laboratories, Harvard University
"RNA Polymerase and Sporulation"
- DR. ERNEST J. STERNGLASS
School of Medicine, University of Pittsburgh
"Nuclear Fallout and Human Health"
- DR. BRIAN J. MCCARTHY
Department of Biochemistry,
University of Washington
"The Expression of the Mammalian
Genome"
- DR. JOHN DALY
NIH, Bethesda
"Factors Affecting Cyclic AMP Formation
in the Brain"
- DR. PAUL S. SYPHERD
Department of Microbiology,
University of California, Irvine
"The Chemistry and Genetics of Ribosome
Assembly"
- DR. WILLIAM C. SUMMERS
Department of Radiobiology, Yale University
"Regulation of the RNA Metabolism of
Coliphage T7 *in vivo* & *in vitro*"
- PROF. ALBERT V. CREWE
Enrico Fermi Institute, University of Chicago
"Observations of Single Atoms Using the
Electron Microscope"
- PROF. NELSON J. LEONARD
Department of Chemistry,
University of Illinois
"t-RNA Components—Chemistry, Spectro-
scopy and Biological Activity"
- DR. JOHN F. WARD
Lab. of Nuclear Medicine, UCLA
"The Biochemistry of DNA Strand Breaks
Induced by Ionizing Radiation"
- PROF. Y. POCKER
Department of Chemistry,
University of Washington
"Carbonic Anhydrase—Catalytic Versatility
and Mode of Action"
- DR. CLAUD S. RUPERT
University of Texas
"Photoenzymatic Repair of UV Damage to
DNA"



shown the capability for detecting low levels of NO_2 and SO_2 from industrial sources. In addition to these trace gases, the use of photographs obtained with polaroid filters for calculating extinction coefficients and particle densities in plumes and air masses are being investigated. In all instances correlations are being made to meteorological conditions co-incident with remote sensor data collection.

Laboratory studies for remote detection of air pollution damage to plants will supplement the air pollution studies. In these experiments, spectral response curves for healthy and damaged plants through use of such devices as multispectral scanners will be determined. Diagnostic spectral trends will then be incorporated into experimental designs for field studies of plant damage.

Pollution damage to plants focuses on sources, types, concentrations, movements, and dispersion of pollutants over an area. Obtaining such data for establishing system relationships with the natural vegetation requires the intensive program in meteorology and air pollution monitoring being undertaken. Also under investigation are the interactions between meteorological conditions and dispersion of pollutants, as well as the effects of pollutants on the surface being studied.

CHEMICAL PHYSICS SEMINAR

Peter M. Hierl and Robert J. Friauf
NASA

The purpose of the Chemical Physics Seminar is to stimulate interdisciplinary activities in the broad areas of overlap among the traditional disciplines of chemistry, physics, and engineering. The principal activity has been seminars at which speakers have been from this campus, from other universities and research institutes throughout the country, and from foreign institutions. The program has brought many outstanding scientists to the campus to deliver seminars covering a wide range of topics in the area of chemical physics. Quantum theory, statistical mechanics, spectroscopy, structure, kinetics, solid state physics, and thermodynamics are among the topics that have been discussed at these seminars.

The project has been extremely successful in causing chemists, physicists, and occasionally other scientists and engineers to discuss problems of mutual interest. Several joint studies, involving two or more faculty members, were inspired by these seminars and are presently being carried out.

The speakers and their topics during the past year were:

- DR. HARRY L. FRISCH
State University of New York at Albany
"Aspects of Transport in Polymers"
- DR. REGINALD MILLS
Australian National University
"Diffusion in Liquids"
- DR. PETER F. JONES
The Aerospace Corporation
"Temperature and Matrix Effects on the Triplet: State Lifetimes of Aromatic Hydrocarbons"
- DR. LARRY HASKIN
University of Wisconsin
"Telltale Trace Elements on Lunar Rocks"
- DR. DAVID SOULE
McDonnell-Douglas Aeronautics
"Magnetomorphic Size Effects in Tungsten"
- DR. TERRY A. MILLER
Bell Telephone Laboratory
"High-Resolution Spectroscopy (Microwave and RF) of Open-shell Molecules"
- DR. PAUL LEVY
Brookhaven National Laboratory
"Radiation Damage Effects in Alkali Halides"
- DR. DONALD M. SPARLIN
University of Missouri-Rolla
"Investigation of the Monotonic Magnetostriction and Magnetic Breakdown in Cadmium"
- DR. RAYMOND J. ACKERMAN
Argonne National Laboratory
"The Chemistry Lanthanides and Actinides at High Temperatures"
- DR. A. M. RONN
Polytechnic Institute of Brooklyn
"Laser Induced Fluorescence in SF_6 "
- DR. DAVID L. FANCHER
Kansas Wesleyan University
"Defect Model of Alkali Halide Solid Solutions"
- DR. KENNETH WONG
University of Southern California
"Theory for Liquid Helium"
- DR. A. MOSCOWITZ
University of Minnesota
"Optical Activity and Molecular Structure"

DR. GERD N. LAMAR

University of California, Berkeley

"Nuclear Magnetic Resonance Investigation of Paramagnetic Complexes with Orbitally Degenerate Ground States"

DR. ELDON FERGUSON

National Oceanic and Atmospheric Administration

"Laboratory Measurements of Ionospheric Ion-Molecule Reactions"

DR. ANDREW YENCH

State University of New York, Albany

"Radiation-Induced Synthesis of Complex Organic Molecules in Interstellar Grains"

THE SPATIAL AND SIZE DISTRIBUTIONS OF INTERPLANETARY DUST AND THE EXTENDED SOLAR CORONA

David B. Beard and Roosevelt Calbert
NASA

Solar eclipse and balloon-borne coronagraph observations of the solar corona out to about 15 solar radii have been analyzed to obtain new and more precise determinations of (1) the electron distribution from 1-15 solar radii from the center of the sun and the velocity of the solar wind as a function of height above the solar surface and (2) the minimum size of interplanetary dust, the light reflection coefficient (albedo) of the dust, the dust temperature, and the minimum distance of the dust from the sun.

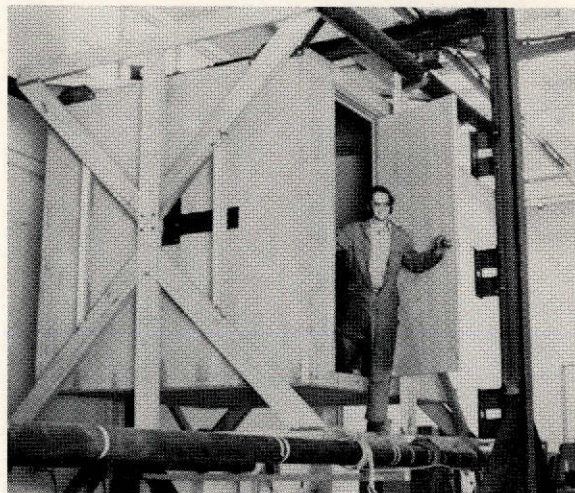
DESIGN AND CONSTRUCTION OF A VIBRATION CHAMBER

Kenneth H. Lenzen, Ronald N. Curry, Gene R. Kendall, and James D. Warner
Biological Research Grant, University of Kansas, Doctor of Engineering Program

The design and construction of a vibration chamber has been completed. The chamber is being equipped to measure the subjects' responses subjectively and objectively and is being instrumented so that various types of psychological or physiological data can be taken.

The chamber can be activated between 1 and 30 cycles per second with free vibration

of acceleration of 1G at one hertz; at higher frequencies, higher accelerations are permissible. There is full control of the damping under free vibration and the chamber will vibrate in a horizontal, vertical, and torsional mode. Other than free vibration in which the original amplitude will be dictated by distortion of the system, a driving system has been designed so that the vibration to be imposed on the occupants (subjects) in the chamber can be programmed.



Vibration chamber.

HUMAN RESPONSE TO VIBRATION

Kenneth H. Lenzen, B. Robert Carlson, Gerald Goldstein, Don R. Justesen, John R. Rupf, Hampton Shirer, John Trank, Edward L. Wike, and Sharron Wike
NASA

Vibrations affect the human being if they are in a low frequency domain, 1 to 30 cycles per second, but the discomfort and fatigue levels have never been determined. The present studies are concerned with defining the subliminal effects and the perceptive effects of vibrations on human beings. Further, the definition of the physiological and psychological effects that accompany relatively low level vibration is desirable. Very light-weight accelerometers for the human frame have been developed for attachment to the subject to determine the attenuation or amplification of vibration through the human system.

Tests have been made on rats to determine the adversiveness of vibration. The first series

of tests have been completed and tests are continuing with animals being subjected to long periods of vibrations to determine their reactions.

In order to vibrate the human being within the acceleration limits defined by the frequency and amplitude parameters set, it is necessary that no noise at this acceleration level be present. As the normal power supply for this type of unit had noise at the acceleration level equal to that of the signal to which the human being was exposed, a power source for the vibration chamber has been developed which contains no noise at the required acceleration level.

POLITICAL AND LEGAL IMPLICATIONS OF THE DEVELOPMENT AND APPLICATION OF REMOTE SENSING TECHNIQUES

Roger E. Kanet, Clifford P. Ketznel, Sandra Hartley, Don Smith, and Henry Vogel
NASA

Analyzing the political and legal implications of the use of remote sensing devices has been the focus of this study. The study included a discussion of the legal and political questions concerning overflight; questions related to the dissemination of the information gathered; questions concerning the role of international organizations in the use and control of remote sensing systems; and other related topics.

GEOLOGY-HYDROLOGY-LYONS, KANSAS RADIOACTIVE WASTE REPOSITORY SITE

E. E. Angino, W. W. Hambleton, C. K. Bayne, J. R. Ward, H. G. O'Connor, J. C. Halepaska, E. D. Goebel, F. W. Preston, L. F. Dellwig, E. J. Zeller, G. Dreschhoff, H. Yarger, and D. E. Zeller

Atomic Energy Commission—Oak Ridge National Laboratories (Union Carbide)

The goal of this investigation was to study in detail the surface geology, sub-surface geology, and ground water hydrology in a nine-square mile area centered on Lyons, Kansas. The Atomic Energy Commission has proposed establishment of a radioactive waste repository demonstration site at Lyons, Kansas. Storage of the waste is to be in the 300-foot

thick Wellington salt bed of central Kansas. Actual placement of the cannisters is intended to be at the 1018 foot subsurface level.

In addition to the Geology and Hydrology, the study included an evaluation of the possible effects of high intensity radiation (radiation damage effects) on salt and a review of the heat transfer problems related to storage of the radioactive and thermally hot material in salt.

These studies have indicated that the shallow water hydrology is more complicated than originally anticipated. Several problems require additional investigation before one can assure the proper safety of this site. Presently, the detailed geology, based on a 6" core from the surface to 1300', appears to be sufficiently known to make reliable heat transfer calculations. Questions regarding low temperature



Two different type core bits used in taking core at Lyons, Kansas, Radioactive Waste Repository Site.

thermal effects (i.e. dewatering of clays) remain. Radiation damage effects appear to be minor, but more data is required to verify this conclusion.

Considerably more work is required to evaluate the coupled stress-strain-thermal model and problems associated with it. To date, this aspect of the safety evaluation of the Lyons, Kansas, site has not been completed.

Additional studies of the shallow water hydrology (drilling, pumping, etc.), the dewatering effects on the clay-rich shale partings of the salt, the shale section, and radiation damage effects on the salt are anticipated in fiscal 72.

A SHORT COURSE IN RADAR REMOTE SENSING FOR GEOSCIENTISTS

H. C. McDonald (University of Arkansas), A. J. Lewis (Louisiana State University), W. E. Waite (University of Arkansas), L. F. Dellwig (KU), and S. A. Morain (KU)

Center for Research, Remote Sensing Laboratory, and KU Division of Continuing Education

Two short courses of one week each were held during the summer of 1971. The courses focused on radar imagery interpretation and terrain analysis for geoscientists and related disciplines serving education, industry, and government. One course concentrated on ge-



On-site examination of Lyons, Kansas, AEC Repository core prior to shipping to Kansas State Geological Survey Laboratories.



The recently completed University of Kansas Space Technology Laboratories.



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KU engineering students assist industry in translating basic knowledge into new products.

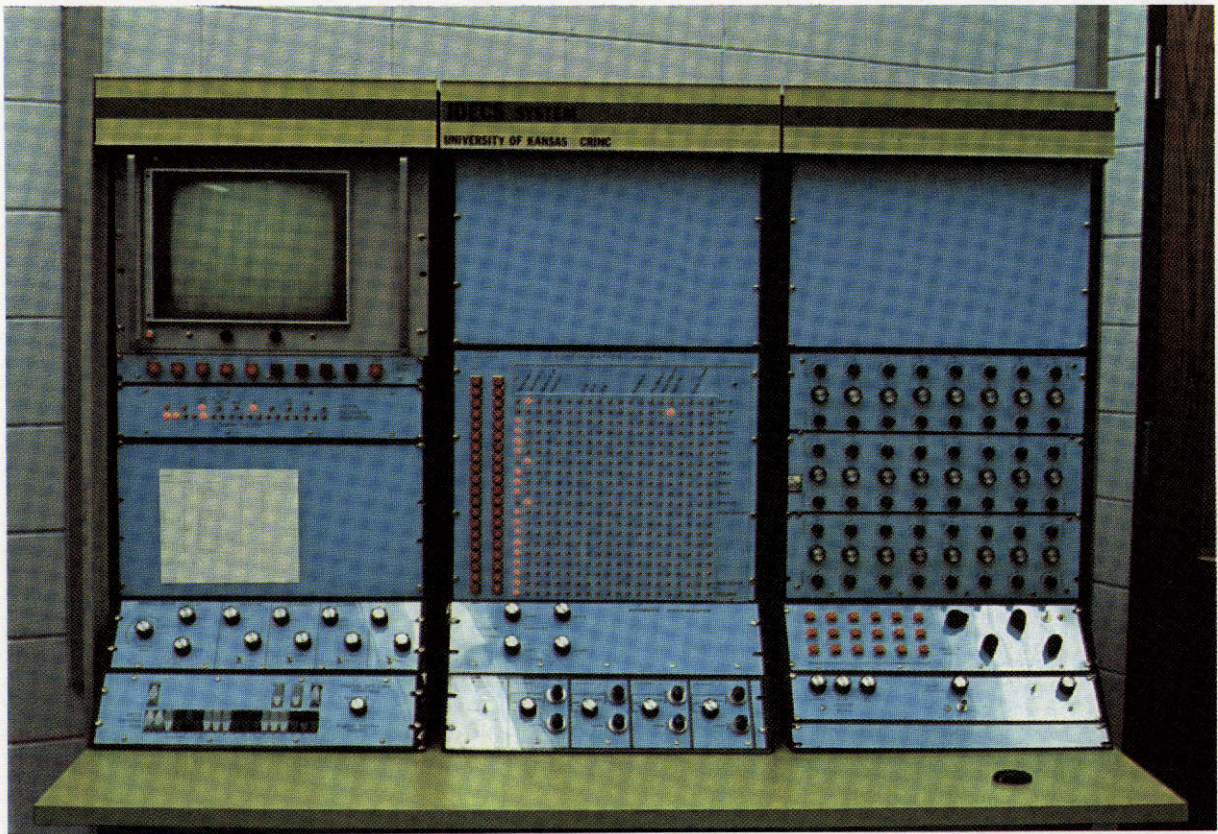


Image Discrimination, Enhancement, and Combination System (IDECS) Control Console.

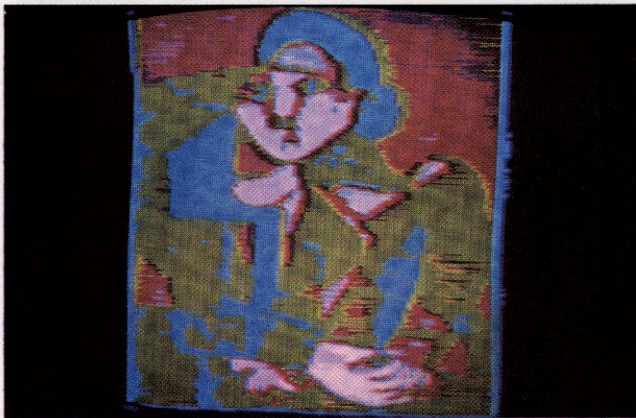


FIG. 1

Figure 1 is an IDECS color-enhanced image of a Picasso painting produced by level slicing the image when input from scanner. Figures 2, 3, and 4 are colored digital images from a high-speed printer.

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FIG. 2

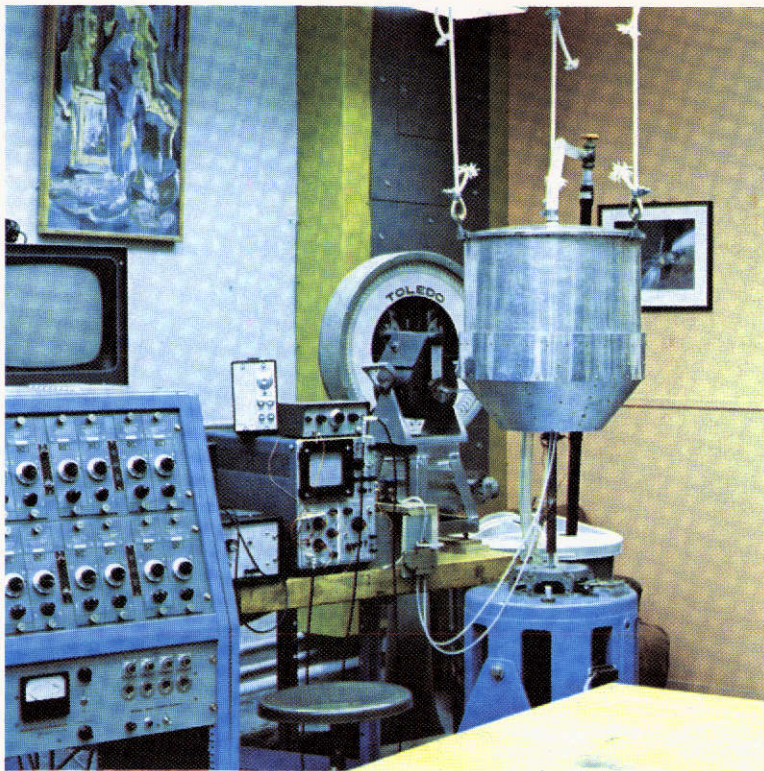


FIG. 3



FIG. 4

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View in Mechanical Engineering Dynamics Laboratory showing a simulated Saturn V fuel tank and dynamic excitation and data acquisition equipment.

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FIG. 1

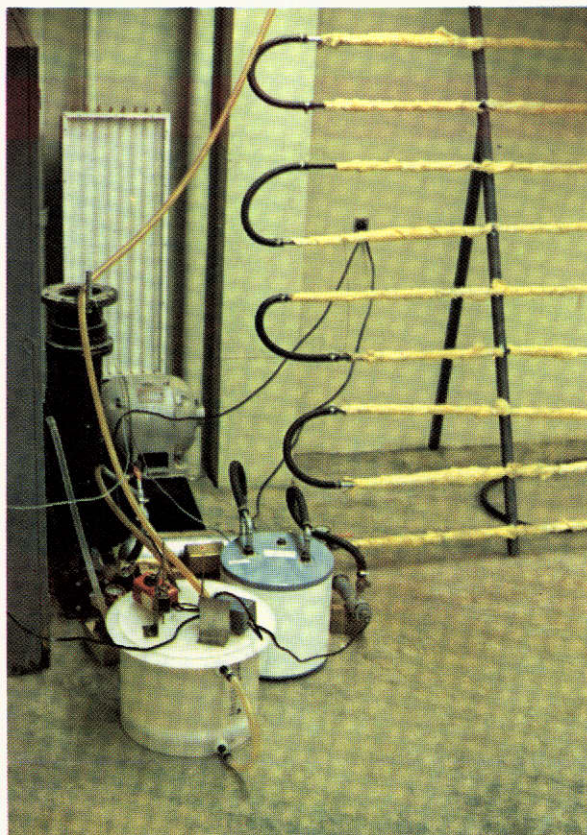
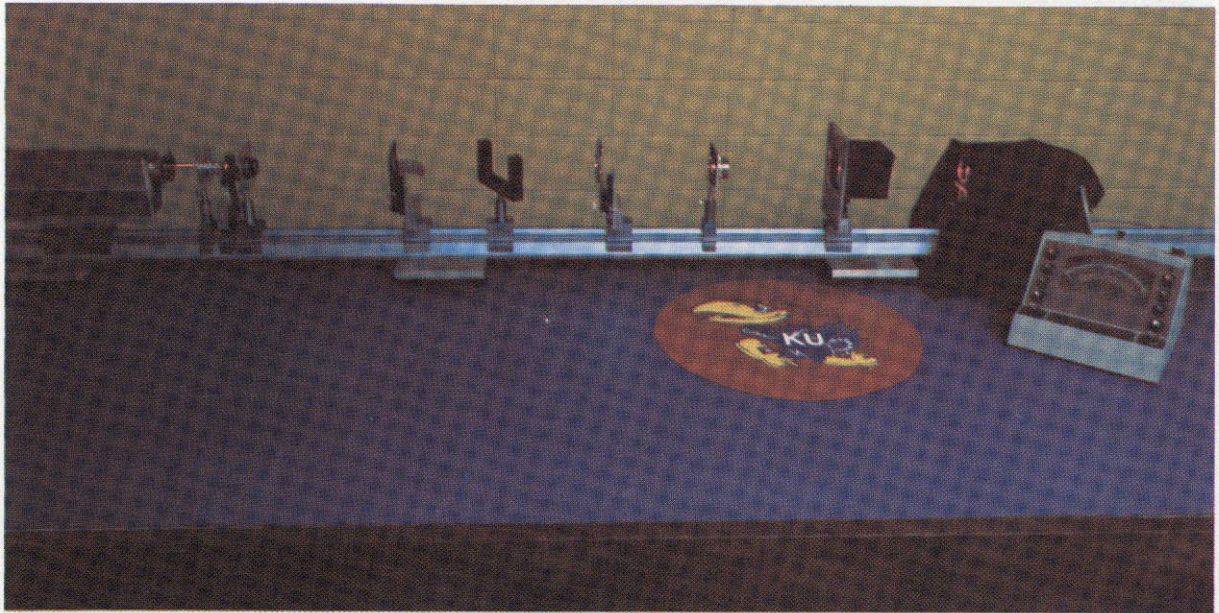


FIG. 2

An Environmental Health Laboratory investigation involved measuring corrosion in various pipe materials; Figure 1 shows the experimental apparatus used to measure corrosion and Figure 2 shows the control devices used in the testing.



Optical data processing (laser) bench used for spatial frequency and texture analysis of remotely sensed images including aerial photographs, spacecraft photographs, and radar images.

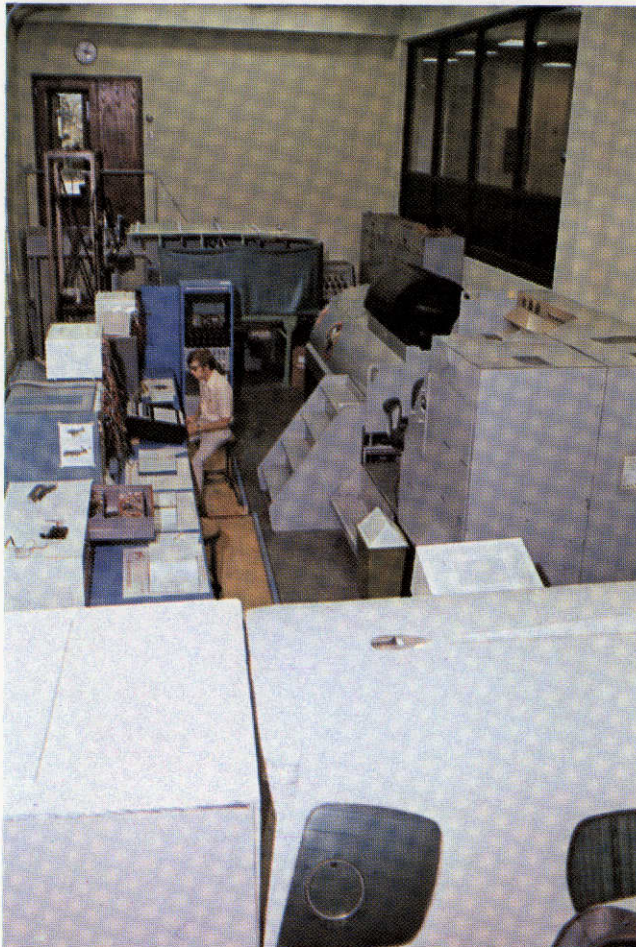


FIG. 1

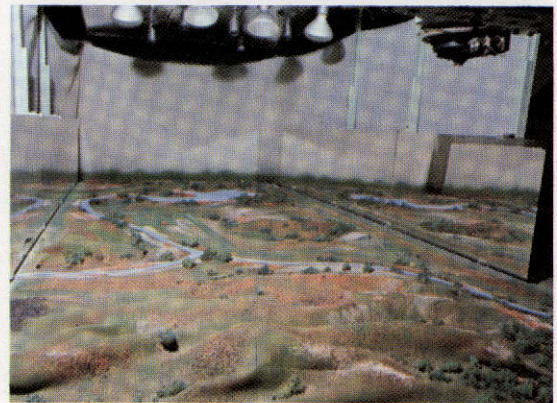


FIG. 2

Figure 1 is a view of the Flight Research Laboratory; an airplane cockpit is shown in the foreground. Figure 2 is a miniature terrain, mounted on a rolling belt, used in simulated flight.

ology and related subjects; the other focused on geography and related areas.

Multidisciplinary team teaching was utilized in the instructional courses which emphasized interpretation principles and techniques providing learning experiences enabling participants to develop integrated understandings of the interaction of electromagnetic energy in the radar wavelengths with terrain. Specific examples of interpreted and annotated radar imagery were used to illustrate interpretive principles and techniques, fundamentals of imagery acquisition, image geometry and distortions and related interpretation problems.

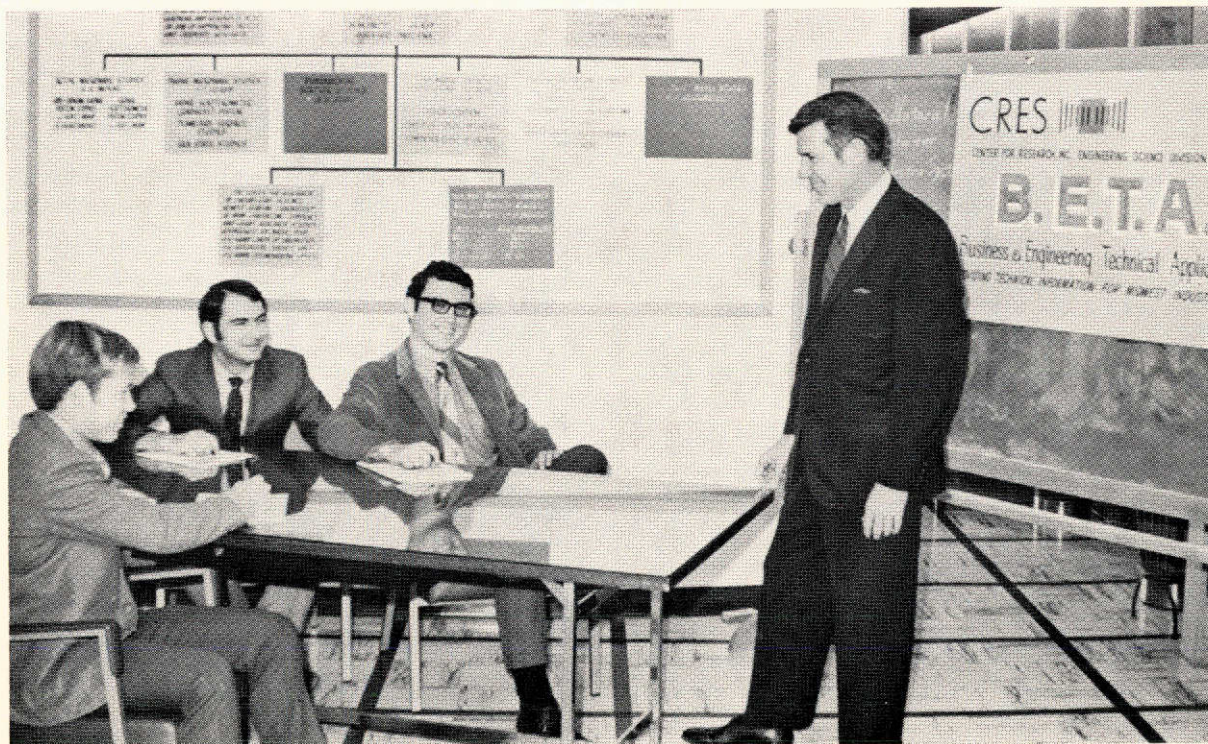
TECHNOLOGY UTILIZATION—BUSINESS AND ENGINEERING TECHNICAL APPLICATIONS (BETA) GROUP

B. G. Barr, Harvey Loucks, and Harold Lowe
NASA

A goal of the National Aeronautics and Space Administration which has received lit-

tle public attention is the dissemination and use of information resulting from space-related research. Established in 1965 with the aid of a small NASA grant, the BETA Group of the Center for Research, Inc., has expanded and sought to achieve this goal. At first, the technical information service of the BETA Group was provided at no cost to industry in the Midwest. When the original NASA grant had been exhausted, the decision was made to continue the service on a non-profit basis by charging companies for the time, material, travel and overhead costs involved. Now, the BETA Group is assisting industry with a broad range of technical problems by utilizing every available source of information.

Undergraduate and graduate students with the ability and the initiative to help industry solve its many and varied problems are encouraged to become Applications Engineers with the BETA Group. Members of this team of students travel throughout the Midwest visiting companies and informing them of the literature search, manufacturers' survey, and other services which are available



BETA Program Director B. G. Barr (right) discusses with Applications Engineers (students) the successful completion of a recent problem posed by industry.

at low cost through the BETA Group. When a problem is referred to the BETA Group, the most qualified engineer is assigned to the project, informed of the project requirements, and expected to complete the project within the prescribed time limit. This engineer is responsible for the project from the time it is assigned until payment is received for the final results. The student thus becomes better acquainted with using library facilities, contacting prominent people in many fields, accounting for costs involved with a project, preparing formal engineering and business reports, following basic administrative procedures, and billing for services rendered. Industry, in return, receives technical information about its problems at a cost substantially lower than other sources of similar information. Also, when a student engineer goes into industry, the time required to integrate him into the company's organization is reduced.

During the summer of 1971, the BETA Group studied problems involving glass packaging, pipe line protection, explosive welding, extraction of bixin dye from the annatto tree, laser cutting, ink jet printing, metal decorating, gyroscope inventions, and more. BETA engineers traveled over 9,000 miles visiting more than 50 companies in five states and delivered reports costing nearly \$5,000.

A contractual agreement was reached with the United Nations Industrial Development Organization in Vienna which will bring numerous industrial problems from developing nations to the BETA Group for study.

The greatest personal reward was received as a result of a project involving an eighty-four year old man and an idea he had been developing for over fifty years. Working with Mr. Rufus Combs of Bolivar, Missouri, refreshed the outlook of the students on the quest for knowledge and its application. Best describing this outlook is an excerpt from one of his letters: "[Education is] . . . The ability to govern one's life in the light of experience. What others have learned and recorded are here for us to profit by, we should go on from there, and learn and record, for others to profit by." The goals of the BETA Group have been developed around this idea and have been reinforced by the devotion of this man to the quest for knowledge.

During the fall of 1971, two members of the BETA Group, Harvey Loucks and Harold

Lowe, prepared a guide for students dealing with information retrieval.

It is the hope of the current members of the BETA Group that assistance may also be rendered to research groups at the University of Kansas and particularly those associated with the Center for Research. The expertise developed by student engineers in the field of information retrieval will permit the BETA Group to provide a technical information service through the Center for Research.

In the future, the BETA Group will continue to disseminate information to industry both regionally and internationally, to assist individuals with technical problems, and to give students practical experience in managing research projects.

THE EFFECT OF SCREW DISLOCATIONS ON THE MECHANISM OF VAPORIZATION OF HIGH-TEMPERATURE CRYSTALLINE MATERIALS

Paul W. Gilles
NASA

The effects of screw dislocations on the strength of materials is well known, and their effects on the vaporization rate, which in many instances is more important than the equilibrium properties in establishing the actual limit of usefulness of materials under high-temperature conditions in ultra high vacuum environments, can be recognized. This investigation has dealt with the effects of screw dislocations on the mechanism of evaporation of high-temperature crystalline materials.

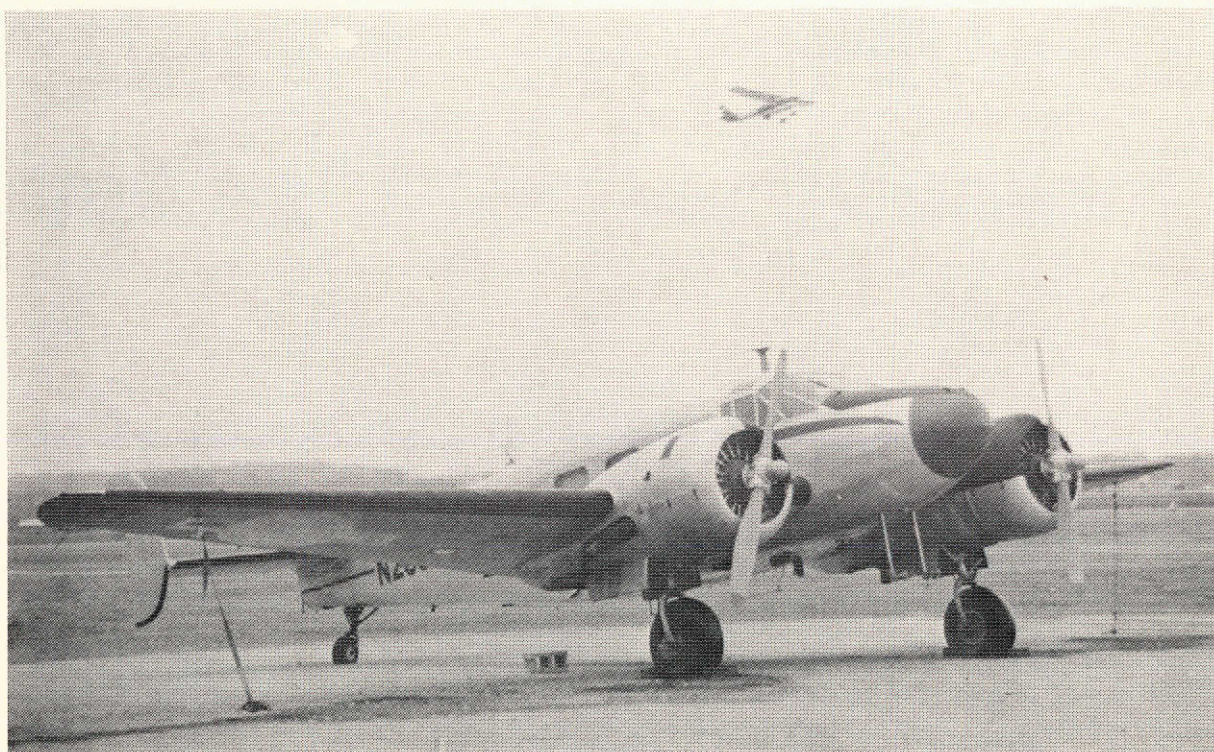
GRAPHICS TECHNIQUES IN MOLECULAR QUANTUM MECHANICS

Ralph E. Christoffersen and Lester Shipman
NASA

Considerable research into the design and implementation of graphics techniques for use with the Honeywell 635 computing system have taken place during the past year. The result is a set of programs that can be used in

a variety of ways. Currently in operation are programs that will plot either the total electron density or the density arising from any given molecular orbital in any specified plane of a molecule. These densities arise from wave functions found by solving the Hartree-Fork equations. In addition, these capabilities can be utilized either on the line printer of the Honeywell 635 computer or the off-line plotter.

Multiple applications of these techniques have occurred, including examination of wave functions for various saturated and unsaturated hydrocarbons, as well as molecules containing nitrogen and oxygen hetero-atoms. Additional research is currently underway to implement these studies in an interactive mode by the use of an interactive graphics terminal. It is expected that these studies will continue throughout the year.



This Beechcraft Model 18 twin-engine craft, recently acquired by the Center for Research, Inc., will be equipped with a radar scatterometer, four Hassleblad vertical-looking cameras, and a metric mapping camera and will serve as a flying research platform for performing experiments in conjunction with earth observations and air pollution research.



THE REMOTE SENSING LABORATORY

R. K. Moore, Director

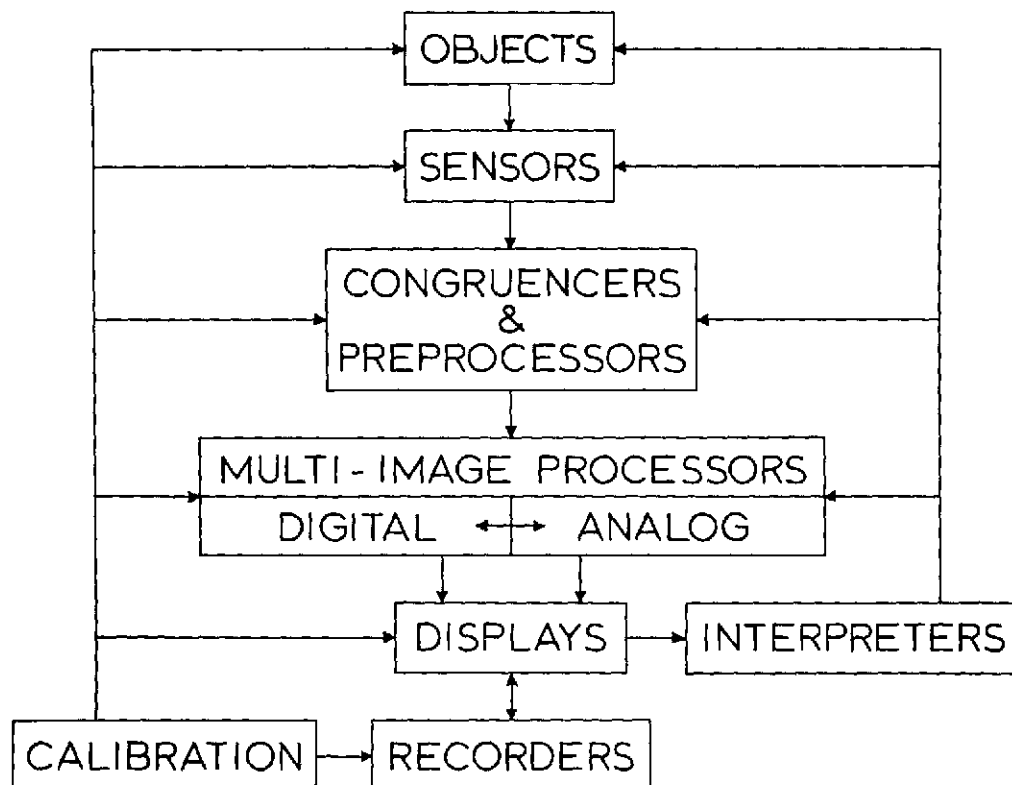
A. K. Fung, Associate Director

The Remote Sensing Laboratory is an interdisciplinary group interested in application of instruments carried on aircraft and spacecraft to sense features of the environment on the Earth and other planets. Major emphasis is placed on the use of microwave radar as a sensor, but images produced by cameras and multi-spectral scanners are also used in the UV, visible and infrared regions of the spectrum. In addition, applications of microwave radiometry are being studied.

The group consists of electrical engineers

interested in the sensor, its interaction with the environment, and data processing, and of users of sensor data including geographers, geologists, botanists, and civil engineers. Effort is continually made to obtain interaction between faculty members and graduate students from the departments representing "customers" of remote sensing and from the two electrical engineering groups.

Remote sensing is viewed as a system, illustrated in the block diagram. To learn about the object sensed without actually being on



THE REMOTE SENSING SYSTEM

the ground beside it, numerous sensor wavelengths and types may be required. Best sensor selection and interpretation depend on knowledge of the interaction between sensor and object, so this is a subject of study. The mass of data generated by multiple sensors flying in high speed aircraft or spacecraft demands automatic analysis or, at the minimum, automatic aids to human analysts. Before automatic techniques can be employed, however, images obtained with different sensors or at different times must be made congruent with each other so that a given point on the ground is simultaneously identifiable on all of the sensor outputs. Some sensors do not produce images, so the problem of correlating the data may involve other techniques besides congruencing.

Data processing may involve either analog or digital techniques, but the data must always be displayed for the human interpreter/analyst, and he must be able to interact with the data processing system. The feedback from the analyst to all stages of the remote sensing process is important and is so indi-

cated in the diagram. For any automatic system to work successfully, calibration is important at all points in the system, as shown.

Activities of the Remote Sensing Laboratory are divided into the following areas, although no rigid organizational structure is used:

1. Object-sensor interaction studies
2. Sensor system studies and development
3. Data processing studies
4. Geoscience application studies

The subprojects of the Remote Sensing Laboratory are presented under these headings.

The Remote Sensing Laboratory is housed in the Space Technology Laboratories. Equipment available includes a Twin Beech aircraft, a multi-spectral camera system using six Hasselblad 70 mm units, an X-band radar scatterometer, the IDECS data processing system (described elsewhere in this section) including a PDP 15/20 and an IBM 7094 computer, a microwave truck-mounted spectrometer for backscatter studies, and an acoustic simulation facility.

OBJECT-SENSOR INTERACTION STUDIES

A SENSITIVITY STUDY OF THE VARIATION OF MICROWAVE APPARENT TEMPERATURE AS A FUNCTION OF THE SURFACE AND ATMOSPHERIC PARAMETERS

S. Wu and A. K. Fung
NASA

A study was made of the relative effect of changes in climatic condition, frequency, water temperature and, consequently, the dielectric constant and the emissivity of sea water on the apparent surface temperature of the sea. This study was carried out for a flat sea model and it provides a comparison between the relative importance of the parameters of the atmosphere and the sea surface in the radiometric observations.

The results indicated that the atmospheric effects are negligible for light and medium overcast but are significant in the presence of

rain. The radiometric measurement is more sensitive to the variation of sea surface temperature when the surface temperature itself is high.

CALCULATION OF MICROWAVE ATMOSPHERIC TRANSMITTANCE UNDER VARIOUS WEATHER CONDITIONS

S. Wu and A. K. Fung
NASA

A study of apparent temperature variation due to a change of transmittance has been made for rain and cloud models proposed by Valley, Holzer, Porter, and Kreiss. Results were plotted for various nadir angles. Thus, if a given model is known to apply to a specific case, the effect of change of transmittance on the apparent temperature can be read off the curves.

THE METEOROLOGICAL EFFECTS ON MICROWAVE APPARENT TEMPERATURES LOOKING DOWNWARD OVER A SMOOTH SEA

S. Wu, A. K. Fung, F. T. Ulaby, and R. K. Moore
NASA

The purpose of this study was to investigate the various weather conditions which affect the apparent temperature measurement looking downward over a smooth sea. These conditions include clear sky, cloudy sky, and the presence of rain. The cloudy sky models examined included three models proposed by Porter (1970), four by Kreiss (1968), three by Neiburger (1949) and three by Levine (1965). For rain conditions, three models by Valley (1965) and two by Holzer (1965) were studied. The apparent temperature versus nadir angle curves were calculated for each model at 8.9, 11.1 and 13.9 GHz for both horizontal and vertical polarizations using appropriate absorption coefficients. The height of observation was fixed at 7 km and the standard atmospheric condition was assumed for the clear sky case. The results of this study are contained in technical report 186-1, which shows that heavy clouds and rain cause large rises in the observed apparent sea temperature at all frequencies studied.

THE EXACT NUMERICAL SOLUTION OF RADIATIVE TRANSFER PROBLEMS IN THE PRESENCE OF RAIN

A. K. Fung and S. Wu
NASA

A numerical technique has been applied to solve the radiative transfer problem to determine the apparent surface temperature of a plane surface in the presence of rain. The rain was assumed uniformly distributed from the surface to 3 km altitude. The sky temperature looking upward from the surface and the apparent temperature looking downward at 3 km height at 13.9 GHz with two different precipitation rates are shown in the following table. A comparison was also made with and without scattering in the table. Results indicate that the effect due to scattering on the apparent temperature measurements is quite significant especially at large nadir angles.

COMPARISON OF APPARENT TEMPERATURE WITH AND WITHOUT SCATTERING AT 13.9 GHz

Apparent Temperature Zenith Angle		Sky (looking upward at $z = 0$ km)										Sea (looking downward at $z = 3$ km)									
Case	Pol.	17°40'	30°40'	40°	50°	60°	70°	80°	90°	100°	110°	120°	130°	140°	150°	160°	170°	180°	190°	200°	210°
Case I precipitation rate = 10 mm/hr Rain temperature = 283°K Sea surface temperature = 283°K Flat sea surface with uniform precipitation rate from 0-3 km	with	Hor	70.7	84.5	118.0	189.7	258.3	182.0	185.5	203.6	245.3	281.0									
		Ver	70.9	84.9	118.2	191.5	260.4	187.0	207.5	243.0	287.7	281.7									
	without	Hor	76.5	91.5	127.6	206.0	282.8	198.6	195.7	217.3	264.5	283.0									
		Ver	76.5	91.5	127.6	206.0	282.8	195.1	216.9	254.1	285.0	283.0									
Case II precipitation rate = 30 mm/hr All the other factors are the same as Case I	with	Hor	171.2	170.9	224.8	352.9	354.5	242.4	247.3	250.8	255.0	252.9									
		Ver	171.5	191.5	226.4	256.4	259.8	243.7	251.4	257.4	255.4	253.0									
	without	Hor	179.0	200.0	236.0	266.5	269.5	260.2	267.2	277.3	282.1	283.0									
		Ver	179.0	200.0	236.0	266.5	269.5	261.5	271.3	281.0	283.0	283.0									

THE EXTINCTION COEFFICIENT, THE SCATTERING COEFFICIENT AND THE ALBEDO OF PRECIPITATION

A. K. Fung and S. Wu
NASA

Previous apparent temperature calculations without exception have assumed negligible scattering effects in the atmosphere. To understand the contribution due to scattering, a computer program was developed to calculate the total extinction and scattering coefficients using Mie's theory and Marshall-Palmer's rain drop distribution function. The program permits variation in frequency, rain drop temperature and precipitation rate. The albedo which is the ratio of the scattering coefficient to the total extinction coefficient was also included.

The results are shown in the table below and it can be seen that the scattering effect is significant at 13.9 GHz and precipitation rate over 10 mm/hr; but for lower frequencies, for example, 8.9 GHz, the scattering effect is less than 10% even when the precipitation rate is as high as 40 mm/hr. Hence, the scattering effect is frequency sensitive and could be significant even for medium rain.

THE EXTINCTION COEFFICIENT, THE SCATTERING COEFFICIENT, AND THE ALBEDO OF PRECIPITATION

Freq. GHz	Precip. mm/hr	273			283			293		
		Coefficients			Coefficients			Coefficients		
		k_m^{-1}	k_s^{-1}	ω	k_m^{-1}	k_s^{-1}	ω	k_m^{-1}	k_s^{-1}	ω
8.9	10	.0318	.00147	.046	.0307	.00151	.049	.0286	.00152	.054
	20	.0729	.00426	.058	.0735	.00440	.060	.0723	.00440	.064
	30	.1185	.00792	.067	.1222	.00821	.067	.1230	.00859	.070
	40	.1669	.01229	.074	.1743	.01278	.073	.1774	.01333	.075
11.1	10	.0558	.00372	.057	.0574	.00383	.067	.0582	.00397	.068
	20	.1251	.01070	.066	.1322	.01101	.083	.1330	.01142	.083
	30	.1968	.01977	.099	.2123	.02031	.095	.2251	.02161	.093
	40	.2777	.03042	.110	.2985	.03148	.105	.3136	.03219	.102
13.9	10	.0942	.00349	.101	.0994	.00371	.098	.1051	.00398	.095
	20	.2065	.01584	.130	.2201	.01740	.124	.2330	.01840	.119
	30	.3253	.04881	.150	.3479	.04959	.143	.3768	.05051	.136
	40	.4465	.07339	.164	.4800	.07609	.159	.5080	.07557	.149

ON BACKSCATTERING FROM TWO-SCALE ROUGH SURFACES

A. K. Fung and H. L. Chan
NASA

The two-scale composite rough surface model usually considered is one made up of large undulations over which small irregularities are superimposed. This general model may be further subdivided into two other models: (1) the large undulations are larger in dimension than that of the illuminated area so that within the beam of illumination the picture is a tilted perturbed plane; and (2) the large undulations are of such a size that at least several undulations can be found within the beam. The first model is essentially the small perturbation model, since the effect of the tilt can be accounted for either by a change in the angle of incidence or by resolving the incident plane wave into horizontally and vertically polarized components, or by both. The second model is much more complicated and has been approached in most cases with a non-coherent assumption, i.e., the contribution from the small irregularities may be computed by summing powers from the large facets constituting the large undulations. The total contribution from the composite surface is then taken to be that from the large undulations plus that from the small irregularities averaged over the large undulations.

If the non-coherent assumption is not made, the total scattered field from the illuminated area must be computed before evaluating the power. This is the approach adopted in this study to calculate both the vertically and horizontally polarized scattering coefficients. The surface is assumed finitely conducting and homogeneous; the surface roughness may be non-uniform. To gain insight into the mechanisms of scatter, results have been compared with those obtained by previous theories.

ON THE INTEGRAL FOR BACK-SCATTERING FROM A RANDOMLY ROUGH SURFACE

A. K. Fung and H. L. Chan
NASA

To study the angular behavior of the usual backscattering integral, a numerical example

has been developed and the integral evaluated without approximating the surface correlation function. Results obtained are compared with approximate analytic evaluations. It is shown that either one of the two possible approximations may be acceptable, depending upon the incident frequency.

COMPARISON OF THE SCATTERING CHARACTERISTICS OF DIFFERENT COMPOSITE ROUGH SURFACE MODELS

A. K. Fung and H. L. Chan
NASA

A study is underway to investigate the differences in the backscattering behaviors predicted by the two-scale composite rough surface models developed by Bass and Bacharov (1958), Semyonov (1966), Wright (1968), Valenzuela (1968), and Fung and Chan (1971).

The backscattering coefficients may be expressed as a function of the following surface parameters: the rms surface slope of the large undulations, m , the standard deviation of the small irregularities, σ_1 , and the correlation distance of the small irregularities, l . The wind dependence of m can be established through slick sea measurements by Cox and Munk (1954). The value of l is determined by approximating the high frequency sea spectrum BK^{-4} with a Gaussian spectrum over the Bragg scatter region. The wind dependence of σ_1 can be assigned by a complete description of the increase in intensity of the high frequency part of the sea spectrum.

A preliminary comparison between the corresponding backscattering coefficients of Semyonov's non-coherent model and Fung and Chan's coherent model in x-band has been completed. The value of kl ($k=2\pi/\lambda$, λ is wavelength) is found to be about 2. Values of $k\sigma_1$, and m used in the comparison are as follows:

$k\sigma_1$	m	corresponding wind speed (knots)
0.15	0.09	11
0.17	0.12	27
0.2	0.15	48

The results show that Fung and Chan's backscattering coefficients are larger than the cor-

responding Semyonov's by 1.5 to 3.7 db for horizontal polarization and by 0–1.4 db for vertical polarization in the range of incident angles 50°–80°. The difference is greater for both larger incident angles and larger m . Comparison with experimental data (NRL, North Atlantic, 1970, and JOSS I, 1971) indicates that scatterings at large incident angles are larger than the theoretically predicted values especially for horizontal polarization. This shows that the coherent theory gives a closer prediction than the non-coherent theory.

BACKSCATTERING FROM ROUGH SURFACES NEAR VERTICAL INCIDENCE

A. K. Fung and H. L. Chan
NASA

A general modified Kirchhoff solution (Fung and Chan, AGARD conference, June, 1971) of the backscattering coefficient, σ_{pp} near vertical incidence for a two-scale rough surface is being studied. Exact results for a chosen correlation function are compared with the corresponding geometrical optics results and results of another possible approximation developed by Fung and Leovaris (see publication list) for σ_{pp} . The correlation function is chosen so that it behaves like a Gaussian near the origin but drops off slower for large values of lag distances. It is shown that over the range of the incident wavelength, λ , where the Kirchhoff method is applicable the predictions of the exact σ_{pp} get closer to those of geometrical optics as λ decreases and to those of the second approximation as λ increases.

SIGNAL RECORDS IN BACKSCATTERING STUDIES

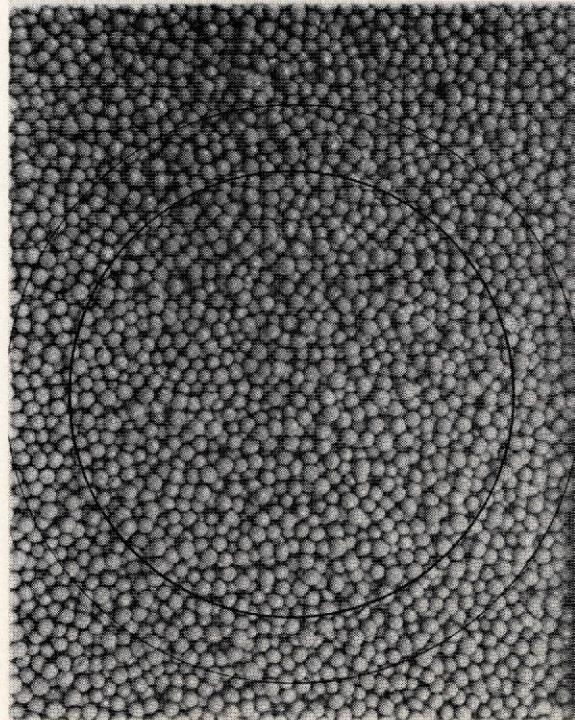
A. Zachs and A. K. Fung
NSF

The analysis of signal-fluctuation records has recently been employed as a potential means for the study of backscattering mechanisms. Investigators of radar sea-echo have observed that Doppler spectra, corrected by subtracting platform motion effects, carried useful information on the mechanism responsible

for the scattering characteristics of the sea. Their reduced data was shown to correlate with roughness parameters like wind speed and surface spectrum. Most of the reported studies on signal clutter and Doppler spectra have been conducted over natural surfaces and hence lack adequate ground-truth information.

An experimental study has been initiated with the acoustic-simulation facility in which signal-fluctuation records have been produced and examined. The experiments are designed to generate a net of signal records from statistically known rough surfaces under a wide range of illumination parameters.

Man-made targets with different degrees of roughness are illuminated by a sonar beam at various angles of incidence and frequencies. The return is measured along a path on the targets by both continuous and step-motion modes. The analyzed records in conjunction with the appropriate scattering theories are expected to answer some questions on the origin of signal fluctuation and the relationship to the parameters of surface roughness.



A model target representing a collection of randomly distributed isotropic and independent scatterers. The inner circle shows the 3 dB beam illumination.

MULTIFREQUENCY MEASUREMENTS OF BACKSCATTERED ENERGY FROM A THIN LOSSY IRREGULAR LAYER

A. K. Fung and A. Leovaris
NSF

Backscatter underwater acoustic measurements were taken at five different frequencies (0.33, 0.54, 0.78, 1.0 and 1.5 MHz) from an irregular rubber layer of uniform thickness supported by an aluminum sheet. The thickness of the rubber layer was 3 mm while the range of the incident wavelengths in water varied from 1 to 4.5 mm. Comparison was made with data taken from a much thicker rubber target (about 1½" thick) of the same surface roughness. It was found that there was no significant difference in the angular behaviors of the return signals for the three lower frequencies. However, at higher frequencies an oscillatory component appeared in the return from the layer target, implying that a layer must be more than about two wavelengths thick for it to be detected. It also indicated that a multi-frequency sensor is essential for exploring unknown terrains with possible subsurfaces.

RADAR AGRICULTURE MEASUREMENTS WITH SCATTEROMETERS

G. A. Bradley and J. C. Holtzman
NASA-MSC and Project THEMIS monitored by the U.S. Army Engineer Topographic Laboratories

The identification of agricultural products using remotely located radar sensors has been a program of continuing interest at The University of Kansas. The research program involves several phases of effort ranging from the theory of radar scatter from terrain and the geographical nature of agriculture terrain to the experimental determination of the dependency of radar scattering response on terrain type. The latter activity has been actively pursued during the summer months of 1970 and 1971 using radar sensors operated by NASA/MSC as well as a radar scatterometer installed on The University of Kansas aircraft.

Three experimental missions were conducted over a test site in western Kansas dur-

ing the summer of 1970 using the radar instruments installed on the NASA/MSC aircraft. These sensors included the two radar scatterometers operating at frequencies of 400 MHz and 13.3 GHz and the side-looking radar operating at a frequency of 16.5 GHz. Experimental measurements have not been completely analyzed, but initial results have indicated that radar can be used to discriminate certain crop types. Further analysis will show any dependency of radar return on length of the growing season, soil moisture, percent ground cover, etc. Two NASA experiments were conducted in the summer of 1971 using the 13.3 GHz scatterometer and the 16.5 GHz SLAR. Data analysis is delayed pending receipt of the processed measurements.

Three experiments were conducted at the Garden City, Kansas, site during the summer of 1971 using the University owned aircraft with a Doppler scatterometer operating at a frequency of 8.9 GHz with vertical polarization. The three experiments were spaced over the growing season of the various types of crops located at this site. Results of the experiments should indicate the degree of dependency of radar scattering return on both crop type as well as period of growing season, soil moisture, and other geographical indicators of terrain type.

The scatterometer measurements permit calibrated signal studies not possible with imaging radars, but the goal is design of optimum imaging radars.

TOWARD RADSCAT MEASUREMENTS OVER THE SEA

J. P. Claassen and R. K. Moore
NASA

In previous aircraft missions over the sea, scatterometer and radiometer observations were often conducted over long traverses in the vicinity of a weather ship. In some cases, remote measurements were actually conducted at large distances from sea truth sources. Even then, mean wind speeds were usually estimated by visually integrating an anemometer reading for short periods of time. Wave conditions were also interpreted by a human observer. To circumvent the prob-

lems in correlating wind and wave measurements by these methods with the remote microwave measurements, well-instrumented, well-coordinated experiments were designed for a combined radiometer-scatterometer sensor (RADSCAT).

The design of the experiments for this sensor indicated that it was also important to regard the ocean surface as a random process whose geometrical characteristics vary statistically over scales of distances both larger and smaller than the area observed by the RADSCAT sensor. To derive a remote measurement of the average wind effect, experiments were designed to spatially sample significant portions of the sea while retaining correlation with the wind.

Intensive studies were also performed to delineate meteorological and oceanographic situations which form the bases for many of the experiments. It was shown that the extratropical cyclone effect many of the wind and wave conditions important to the oceanographer and meteorologist.

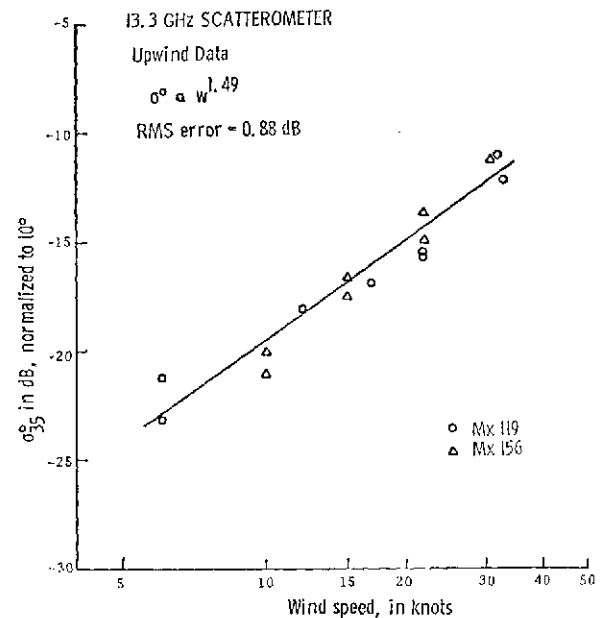
In these planning efforts, features were embedded in the experiments to exploit the benefits of interpreting information from near simultaneous observations by the composite instrument. Detailed descriptions of these experiments are available in Technical Reports 186-2 and 186-3.

RADAR SCATTEROMETER OCEAN MEASUREMENTS

R. K. Moore, G. A. Bradley, and J. C. Holtzman
NASA-MSC

An experimental program has been continuing since the spring of 1966 with the objective of calibrating the radar scattering coefficient dependence on ocean surface wind speed and direction. It has been proposed to use a radar scatterometer mounted on a satellite or a fleet of aircraft to measure the ocean surface wind speed by measuring the radar scattering coefficient and thus predict weather on a global scale through the use of remote sensors. The majority of the early experiments resulted in inconclusive evidence of the dependence of radar scattering coefficient on wind speed because of equipment problems and/or insufficient knowledge of the surface

wind speed and direction. The JOSS (Joint Ocean Surface Study) experiments conducted in 1970 and 1971 over the North Atlantic Ocean successfully measured wind speeds ranging from 6 to 33 knots using the 400 MHz and 13.3 GHz radar scatterometers. Results from these experiments have shown that little or no dependence of the scattering coefficient on wind speed exists at a radar frequency of 400 MHz. However, there is a strong dependence of scattering coefficient on wind speed and direction at a radar frequency of 13.3 GHz. The accompanying figure shows the relationship between the radar data and the surface wind speed to be power law with an exponent of 1.49 for upwind flight and radar incidence angle 35°. In general, the exponent decreases for lower incidence angles and for crosswind flight direction. A statistical analysis of the radar prediction and a comparison with the statistics of anemometer measurements have shown that the radar prediction accuracy is within the accuracy of the anemometer measurements. It has been concluded that a radar scatterometer operating at a frequency of 13.3 GHz can be used to remotely sense the wind speed and direction over the ocean surface.



Relationship between radar data and surface wind speed using exponent of 1.49 for upwind flight and radar incidence angle 35°.

RADAR SEA ICE MEASUREMENTS

**G. A. Bradley, J. C. Holtzman, R. K. Moore,
and A. W. Biggs**
NASA-MSC

The University of Kansas has been responsible for research associated with a NASA/ MSC program designed to remotely sense arctic sea ice using airborne radar sensors. The radar scattering properties of arctic sea ice have been measured on two experimental research flights using NASA instrumented aircraft. Mission 47 was conducted in the vicinity of Pt. Barrow, Alaska, in May 1967 using a radar scatterometer with an operating frequency of 13.3 GHz. Aerial photography provided the sea ice type identification for correlation with the radar signatures. Results of the data analysis of this mission have shown that radar scattering coefficient varies as a function of ice type. Further measurements of the dependency of radar scattering coefficient on ice types were made in April 1970. Two radar scatterometers were used in the experiment; one operating at a frequency of 400 MHz, utilizing dual-polarization and one operating at a frequency of 13.3 GHz and vertical polarization. In addition, a side-looking airborne radar (SLAR) operating both in the real aperture and synthetic aperture modes at a frequency of 16.5 GHz was used in an effort to identify ice type and to map the dynamics of ice movement. Initial analysis of these data show a dependency of the radar scattering coefficient on ice type and show that ice movement can be mapped using imaging radar techniques.

VOLUME SCATTERING FROM SEA ICE AND GLACIER SNOW

Albert W. Biggs
Naval Ordnance Laboratory

This study considers volume scattering from Arctic sea ice and Cascade Mountain snow fields. Physical properties of sea ice and dielectric properties of glacier snow were described in terms of dielectric mixtures and the relaxation spectra of water at microwave frequencies. The VLF spectrum was included to illustrate analogous relaxation for ice. Scattering models were brine pockets in sea ice

and ice spheroids in snow fields. Interpretations of radar backscatter measurements of sea ice and SLAR images of snow-fields were made with these models. Simulation of sea ice in an acoustic tank was used to demonstrate volume and surface scattering with good qualitative results. The dielectric relaxation phenomena in water at microwave frequencies was also interpreted as a mechanism for anomalous behavior.

SEA ICE DISCRIMINATION WITH RADAR SCATTEROMETERS

A. W. Biggs, R. M. Haralick, and R. K. Moore
Naval Ordnance Laboratory

Interpretations for backscatter radar returns were made in terms of surface roughness, volume scatter, effective conductivity, and relative dielectric constant of the scattering media. These interpretations, made with respect to statistical analyses of 13.3 GHz backscatter of various categories of sea ice at different angles of incidence, indicate that it is possible to identify both water or thin ice and multi-year ice from first-year ice without any misidentifications using angles of incidence greater than fifteen degrees. Further, it seems possible to identify a few additional ice categories within the first-year ice group.

The area coverage requirement of a given sea ice category, in terms of aircraft operating altitude, speed, antenna patterns, and signal frequency, was determined with the description developed covering the minimum terrain area necessary for discrimination against other sea ice categories.

DESIGN AND CONSTRUCTION OF A RADAR SCATTEROMETER

**Albert Biggs, David Fayman, and
Robert Matreci**
Naval Ordnance Laboratory

A 9.375 GHz Radar Scatterometer has been designed and constructed at CRINC for measuring the radar backscatter of terrain at various angles of incidence. The system op-

erates in CW mode and uses separate phased array transmitting and receiving antennae which illuminate a long but narrow patch of ground beneath the aircraft test bed. During the ground based data reduction, the power in the backscattered return for selected angles of incidence was computed, and a graph of the average radar backscatter cross section, σ_0 , versus angle of incidence was drawn. Using such curves derived from flights over arctic ice, design information will be obtained to be applied to systems which determine ice types and measure thickness.

SCATTEROMETRY TECHNIQUES FOR SENSING ARCTIC SEA ICE THICKNESS

A. W. Biggs, D. Fayman, and R. K. Moore
Naval Ordnance Laboratory

After several thorough studies on the error sensitivities of the scatterometer, the CW radar scatterometer was completed in the latter part of 1970. After installing the scatterometer on The University of Kansas airplane, initial flights were made in the vicinity of Lawrence, Kansas, with later flights being made in the area of nearby Lake Perry.

With investigators accompanying the scatterometer, a flight over the Arctic sea ice was made in the spring of 1971, and the scatterometer performed as expected. Preliminary analysis of the Doppler-shifted backscatter indicated a good differentiation of sea ice roughness.

Three technical reports have been written on arctic sea ice and scattering therefrom; antenna patterns of dipole antennas in arctic terrain are described in terms of the effects on specular return from ground markers or transmitters. Volume scatter and the effects of dielectric mixtures of snow, ice, and water are combined with some excellent results from deLoor and others. Beacon antenna anomalies are described for high frequency systems with experimental results from Canadian workers in the Alert-Thule region. Another paper presents a statistical program for data analysis using Bayes decision rules. (See A. W. Biggs in the Publications List for bibliographical information on these papers.)

COLLECTION OF SCATTEROMETER DATA OVER THULE, GREENLAND, AND ALERT, CANADA

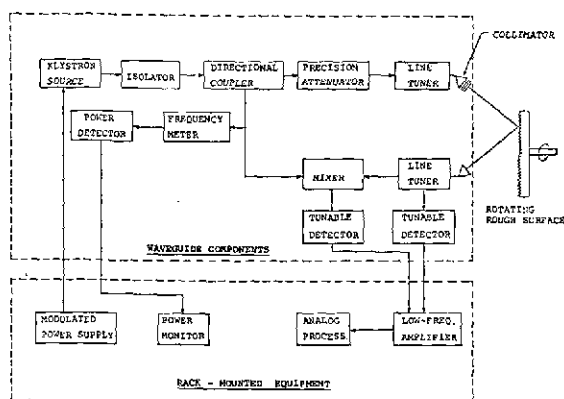
David Fayman and Robert Matreci
Naval Ordnance Laboratory

Using the Remote Sensing Laboratory designed-and-built X-band radar scatterometer, data was collected from flights over the annual ice near Thule, Greenland, and the multi-year ice near Alert, Canada. This data will be used to investigate the feasibility and design parameters for radar systems that would differentiate arctic ice types and give ice thickness information remotely from aircraft. As this data is analyzed, important information from ice penetrometer (instrumented projectiles for ice thickness measurement) drops by the Terradynamics Group of Sandia Laboratory and extensive ground truth collection by the U.S. Coast Guard Geology Laboratory will be included and should provide a sound basis for decisions on further work in the ice identification by radar area.

A COMPLEMENTARY MICROWAVE SYSTEM FOR BACKSCATTERING MEASUREMENTS

A. K. Fung and A. Zachs
NSF

Most past and present experimental studies on the backscattering of known rough surfaces have been conducted in the sonar simulator. The low frequencies of illumination facilitated a simple system for backscattering measurements in the millimeter range of wavelengths. The accumulated experience in target construction and analysis as well as in data interpretation promoted the need for a more complex experimental tool. Since the simulator is limited to scalar scattering only, a microwave millimeter system was designed to complement the simulator and thus extend the nature of the experiments into the vector space. Scanning the reported data from controlled experimental study, the lack of adequate information on depolarized backscattering is observed. The composite system enables the use of the same target in both longitudinal and transversal illumination at the



Schematic diagram of CW system.

same wavelength which, consequently, yields two channels of information toward the formulation of backscattering mechanism. The system is basically a CW communications link with the rough surface as a passive repeater.

WIND WAVE EXCITATION OVER GRAVITY WAVES—A TWO-SCALE SEA SIMULATOR FOR SCATTERING EXPERIMENTS

A. Zachs and R. K. Moore
Naval Oceanographic Office and NASA

Most of the water-tank simulators for the study of the characteristics of radar sea-echo have agitated the water surface by either mechanical or wind waves. Whenever a wind source was used it was usually a wind tunnel with the water as the bottom side. A different method of surface generation has been tried to address the problem of a two-scale sea simulator. The longer waves have been excited by a mechanical agitator in the water, and the wind waves were superimposed on the gravity waves by a wind tunnel blowing at about 4" above the mean surface level. The wind tunnel was designed to break all large scale turbulence and adjusted to minimize the enhancement of the gravity waves. A relatively short pitch, about 2 ft., was required to achieve a stable but rough surface.

Preliminary results indicate the feasibility

of generating a two-scale surface with independent control on each scale. This will facilitate a study on the effects of gravity waves and capillary waves on the scattering characteristics of the sea with adequate information on each scale of roughness as well as the composite surface.

THE CONSTRUCTION OF A COMPOSITE ROUGH TARGET FOR BACKSCATTERING EXPERIMENTS

A. K. Fung and A. Zachs
NSF

The concept of a composite model in backscattering theories has recently evolved and gained wide use. In the basic model the roughness of the scattering surface is described as a combination of both large and small scales of roughness where the scale size is determined with reference to the illuminating wavelength. The two scales are considered to scatter either coherently, or as independent sources; however, the model is required to be such that the statistical properties of each scale be generated by an independent random process.

An experimental study has been conducted to construct a man-made target which will qualify for such a composite model. The guiding procedure was chosen so as to roughen the target in a sequence of two independent processes, each yielding a different scale of roughness. The statistical parameters of the first process and those of the composite surface were measured. The second process was based on the tested difference between the two measured profiles.

It was found that the superposition of two scales of roughness required involved methods for both surface deformation and profile measurements. If a metallic surface was used, then the construction of a small scale roughness was also producing large scale structures since the deformations were not easily confined to the small structures. The use of a plastic mold hindered the efficiency of intermediate profile measurements during the stage when the mold was kept soft and ready for the second process.

Sonar targets can be constructed from plastic molds if the profile can be measured with a non-contact device, such as a photograph, and then applied to an optical processor. As for the metallic surfaces, investigations using a randomly-shaped key die to impress the fine scale structures on the surface will be conducted.

A 4-TO-8 GHz RADAR SPECTROMETER AND BROAD BANDWIDTH IMAGER

W. P. Waite, R. K. Moore and Ron Moe
NASA and Project THEMIS monitored by the
U.S. Army Engineer Topographic Laboratories

A ground based mobile radar system capable of continuously swept operation over the frequency range of 4-8 GHz was designed and constructed. The system makes use of a so-called "slow-sweep" technique to provide illuminating bandwidths that range from approximately 10 MHz to the full 4 GHz range.

In the "slow-sweep" mode of operation the transmitter frequency is continuously swept across part or all of the 4 GHz bandwidth at

a relatively slow rate. This swept signal is pulse modulated at a repetition rate much faster than the sweep rate; thus the transmitter output is a succession of pulses each at a slightly different carrier frequency. By suitable choice of the relative rates and the pulse width the spectra of the pulses are overlapped giving an almost uniform output spectrum over the sweep range.

The average amplitude of the return pulses is, in essence, a sampled data record of the target spectral response across the swept band. The sampling window spectral width is that of the individual amplitude modulated pulse. Postdetection averaging of successive pulses enables one to obtain an effective bandwidth as broad as the sweep range. The fine control of effective bandwidth permitted by such averaging in frequency permits investigation of the effect of bandwidth or panchromatic illumination upon the fading return of complex targets.

Problems of non-uniform frequency response of antenna and system components are partly alleviated by comparing target returns with those from a sphere of known characteristics.

The need for multiple receiving channels to investigate possible spectral signatures is overcome by recording B-scan images of area extensive targets for several panchromatic bands. The resultant panchromatic images are then combined to produce false color "polypanchromatic" images from which spectral signature identification may be attempted.



Polypanchromatic radar system.

CW MODIFICATION OF THE MICROWAVE BROADBAND SPECTROMETER

R. K. Moore and Ronald D. Moe
NASA and Project THEMIS monitored by the
U.S. Army Engineer Topographic Laboratories

The 4-8 GHz microwave spectrometer previously described is restricted to ranges in excess of about 80 feet because the short pulses circulate in the microwave circuitry sufficiently long to reduce receiver sensitivity at shorter ranges. This was not a serious restriction on the earlier measurements made from a rooftop, nor is it a restriction on imaging measurements. Shorter range capability is

needed with the available boom truck to make vertical incidence spectrometric measurements.

To overcome this problem, the system was modified for short range performance in a continuous-wave mode. Both frequency modulation and amplitude modulation techniques were considered and tried. The amplitude modulation, by a sine wave, made possible detection of the response by filtering out the received side bands. This method suffers, however, because it is restricted to a resolution determined by the antenna beamwidth at vertical incidence and nearby. This resolution is inadequate. Consequently, the frequency modulation system was selected. With this technique, the frequency modulation capability of the laboratory oscillator used as a driver for the system could be exploited to produce a return signal whose frequency difference from that transmitted is a function of range. A suitable narrow-bandwidth filter was constructed to separate out a particular range cell. The range at which the cell was found was established by varying the frequency deviation rate.

This system could be used to extremely short ranges and also was adequate out to angles of incidence of about 70° or beyond. At the steeper incident angles, no amplification is required beyond the output level of the swept commercial oscillator; however, at the shallow incident angles, the use of the power amplifier was necessary.

The frequency range of this system is being extended to cover the range 8-18 GHz.

SPECTRAL RESPONSE MEASUREMENTS IN THE MICROWAVE REGION

W. P. Waite, R. D. Moe, R. K. Moore and
H. Razaghi-Khamisi

NASA and Project THEMIS monitored by the
U.S. Army Engineer Topographic Laboratories

The microwave spectrometer was used to produce responses from a variety of targets while it was mounted atop a dormitory building. The spectral responses made with relatively narrow bandwidth exhibited the anticipated fluctuation due to phase interference. For bandwidths of about 500 MHz, the small fluctuations become relatively unimportant at the resolution bandwidth used (40 MNz).

Measurements of the return from an isolated car on a parking lot showed a wider frequency spacing between the fluctuations. For this target, a larger bandwidth was required to reduce the fluctuations to an acceptable level. This is expected because the extent of the car was less than the size of the illuminated area, but nearly all of the return came from this smaller region, so the result was equivalent to using a narrower illuminated region or a wider resolution bandwidth.

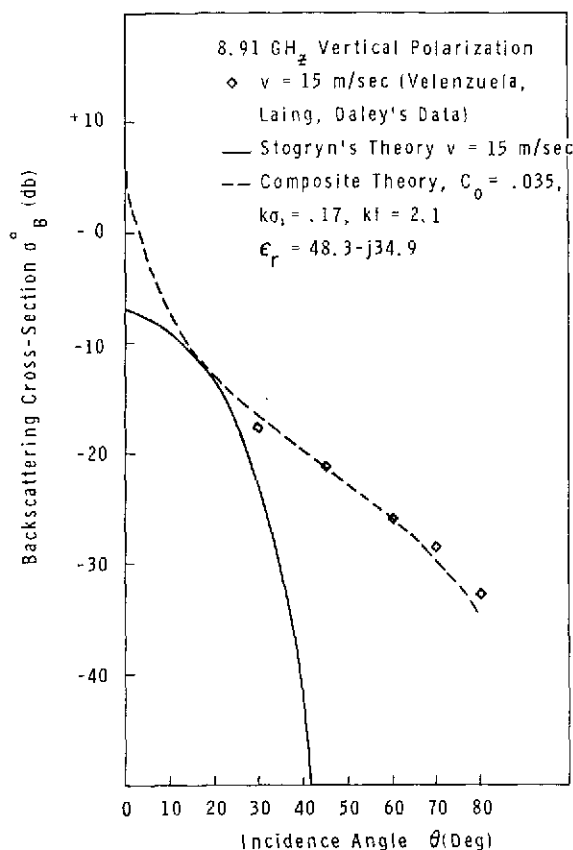
The smoothed spectral response curves were normalized and compared with normalized spectral responses in the optical/near-infrared region. Variability of the microwave response and the optical-infrared response was surprisingly similar in general characteristic and amount. The total difference in level between different responses in the microwave region exceeded that reported by others for the visible-infrared region, but the shape was about the same with the same percentage variation in level across the band.

These measurements were extended to include numerous samples of field crops, such as corn, alfalfa, and soybeans. At the time of writing, the results of these measurements are incomplete. Differences appear among the crops having significant variations in shape or moisture content, but the degree of the difference and its uniqueness has not yet been determined in the data analysis.

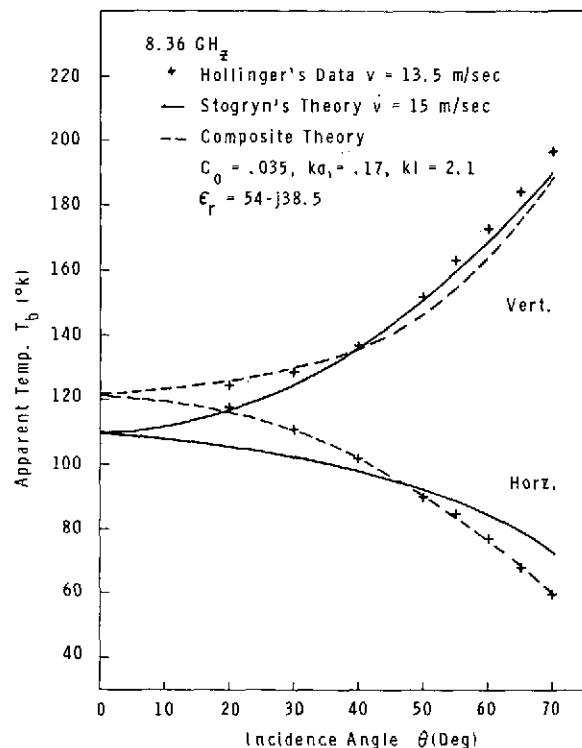
THE MICROWAVE EMISSION FROM THE SEA

A. K. Fung and S. Wu
NASA

A composite surface model was used to calculate the differential scattering coefficients and the emissivity of the sea surface at different wind speeds. The assumed surface model consists of two scales: the small scale roughness was assumed to have a spectrum which decreased approximately like k^{-3} for incident angles between 20° - 70° where k is the wave number of the small scale roughness; the large scale roughness was assumed to satisfy the tangent plane approximation. Parameters in the surface model were determined by fitting the theoretical model to the



Comparison of radiometric and scatterometric results at 8.91 GHz.



Comparison of radiometric and scatterometric results at 8.36 GHz.

experimental data obtained by Guinard and Daley (1970) and Valenzuela et al. (1970). Scattering cross sections with surface parameters so determined were used for computing the surface brightness temperature. Comparison between the measured brightness temperature obtained by Hollinger (1971) at 8.36 GHz and 1.41 GHz and the predictions of the assumed surface models were made for two different wind speeds. The composite model allows closer agreement with both scatterometric and radiometric data than the single surface theory used by Stogryn. To establish the validity of the composite surface theory more experimental data at different frequencies and wind speeds are needed. However, this study indicates that the composite theory allows correct predictions for both scatterometric and radiometric data. Figures 1 and 2 show the comparison with both radiometric and scatterometric results at 8.36 GHz and 8.91 GHz respectively.

EFFECT OF ANGULAR VARIATION ON TERRAIN SPECTRAL REFLECTIVITY

D. D. Egbert and F. T. Ulaby

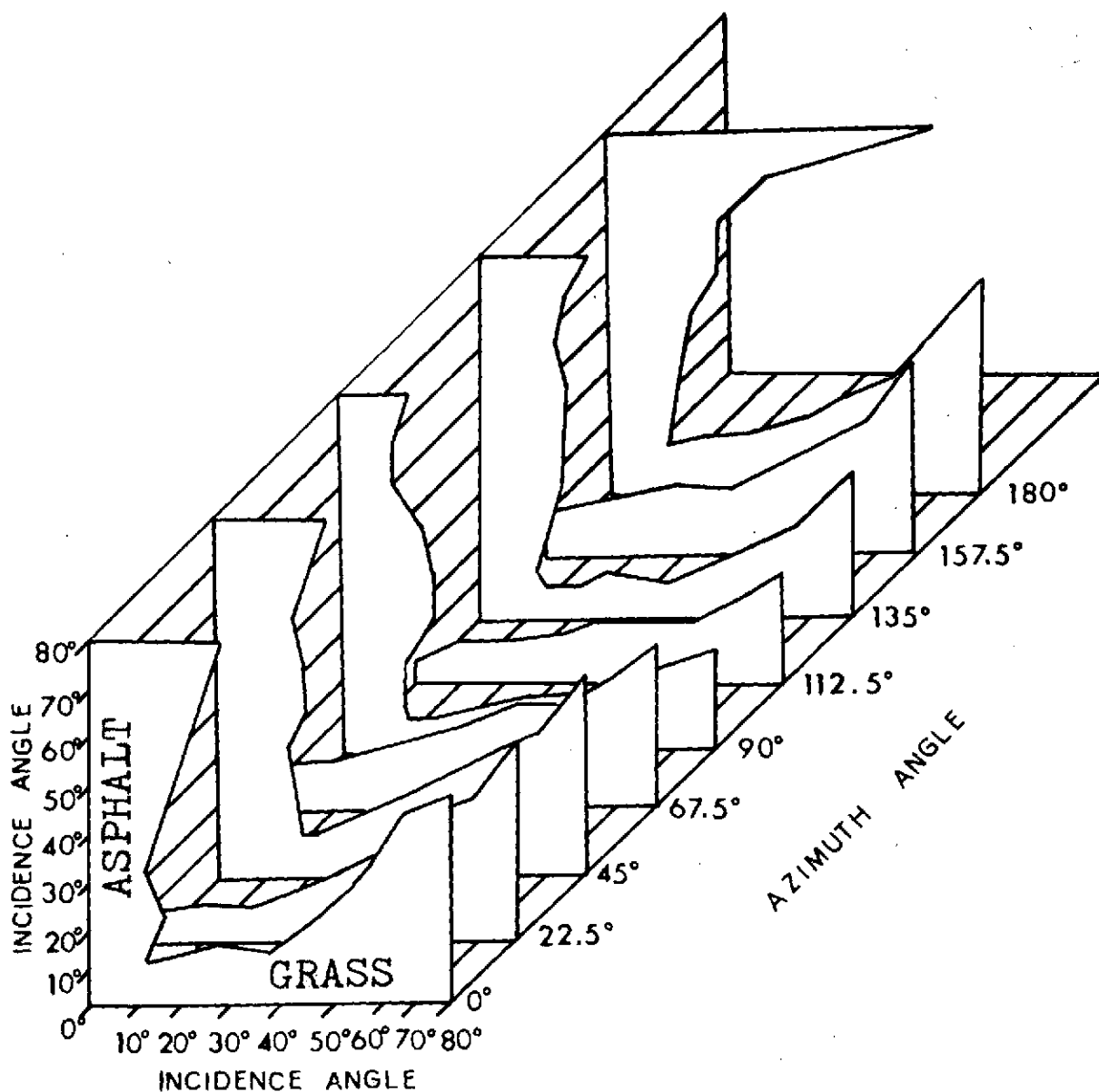
NASA and Project THEMIS monitored by the U.S. Army Engineer Topographic Laboratories

Under varying combinations of solar altitude, azimuth, and incidence look angles, the appearance of the same object on aerial photographs may change drastically. This is due to the angular variation in reflectivity exhibited by all natural objects. This variation of reflectivity is not the same for all objects; thus, if the exact variation of two different objects is known, it is possible to control the angles to enhance the difference in their appearance on aerial photographs.

In order to determine the exact nature of these variations an experiment was designed to measure the spectral reflectance of specific targets under controlled angle conditions. The test was made on two examples: Kentucky 31 Fescue grass and asphalt paving. These two targets are exemplary of two wide

classes of targets of interest in remote sensing. First, the asphalt is relatively smooth and typical of many man-made targets such as roads, building roofs, etc. The grass is typical of natural vegetation and certain types of small-grained agricultural crops. The range over which each angle was varied was as follows: solar altitude, 15° to 70° ; incidence look angle, 10° to 80° ; and azimuth angle, 0° to 180° . It was found that the contrast ratio between asphalt and grass is normally 2:1;

however, under certain conditions this ratio may reverse to as much as 0.5:1, i.e., grass can exhibit twice the reflectivity of asphalt instead of the normal one half. A convenient method for graphically displaying the reflectance variations for two objects is shown for asphalt and grass for a solar altitude of 15° . A graph similar to this can be constructed for any two objects, and it is a convenient way to determine the proper angles for a remote sensing mission which will provide maximum con-



Angular variation in panchromatic grass and asphalt reflectance at solar altitude of 15° .

trast between the two objects to be differentiated.

GROUND WAVE PROPAGATION OVER ARCTIC SEA ICE

Albert W. Biggs

Naval Ordnance Laboratory

Radio ground wave propagation in the

Arctic Ocean occurs over mixed paths which include layered or homogeneous sea ice and sea water. Amplitude and phase variations occurring as "dropoff" or "recovery" effects at the ice-sea water boundaries provide a technique for sea ice mapping and an explanation for anomalous radio reception. The phase variations were found to be more sensitive over short distances from the mixed path boundaries.

SENSOR SYSTEM STUDIES AND DEVELOPMENT

BROAD SPECTRUM IMAGING RADAR

W. P. Waite and R. K. Moore

NASA and Project THEMIS monitored by the
U.S. Army Engineer Topographic Laboratories

The microwave spectrometer-imager was used to produce monochromatic and panchromatic images to illustrate the improvement obtainable with frequency averaging. The decrease in scintillation of the panchromatic imagery materially aided the recognition of target, tone, and shape. Multiple panchromatic images were combined into a color display to illustrate the potential of polypanchromatic illumination as a means of identifying spectral response characteristics. The combination suffered somewhat because of the difference in antenna beamwidth from one edge of the band to the other, and the consequent difference in resolution.

The frequency variation of the return from a discrete scatterer model was examined theoretically for a variety of illuminating conditions ranging from minimum bandwidth needed for resolution through bandwidth far in excess of resolution requirements. Theoretical reduction in return variance was shown to be a function of the resolution band-

width and illumination bandwidth ratio. That is, the improvement is proportional to the square root of the ratio of the bandwidth actually used to that required for range resolution.

PANCHROMATIC ILLUMINATION FOR RADAR—ACOUSTIC SIMULATION OF PANCHROMATIC RADAR

G. C. Thomann and R. K. Moore

NASA and Project THEMIS monitored by the
U.S. Army Engineer Topographic Laboratories

Monochromatic or near-monochromatic signals suffer from fading used by the coherent addition of signals scattered from facets within a target or resolution cell. Fading in communications systems, glint in tracking radars, lower probabilities of detection in search radars, and grain and target break-up of imaging radars result from the use of narrow band signals. Panchromatic (wide-bandwidth) signals can be transmitted and a return averaged over the bandwidth to reduce the fading.

Analysis shows that use of wide bandwidth signals can improve performance in both tracking and detection radar. The improvement for an imaging system has been derived as a function of bandwidth. A sharp-edged scattering target composed of many isotropic scatterers was used as a model that leads to the Rayleigh-distributed return characteristic of most natural targets. For relatively large bandwidth, the reduction variance of the signal return from such a target was shown directly proportional to the averaging bandwidth. The ultrasonic simulation system of the Remote Sensing Laboratory was operated as a sidelooking real-aperture imaging radar (sonar) to demonstrate the image improvement obtained with panchromatic signals. The usual narrow-bandwidth ultrasonic transducers have their bandwidth broadened by use of quarterwave mechanical matching, and electrical tuning.

Both statistical and imaging experiments were done. The return distribution from a homogeneous surface was shown to be nearly that of the Rayleigh model. A frequency averaging experiment was done to demonstrate the variance reduction. Monochromatic and panchromatic images were made of area-extensive model targets. The monochromatic images demonstrate grain and target breakup; the panchromatic images show a reduction of these effects and demonstrate the degree of improvement to be expected from an electromagnetic system.

Because it was possible to control the characteristics of the target in this experiment and to simulate an airborne side-looking radar, some of the demonstrations of improvement were more striking (although no more valid) than those achieved with the B-scan image produced with the electromagnetic system mounted on a building, mentioned in another project description.

EXTRACTING QUANTITATIVE DATA FROM PHOTOGRAPHICALLY RECORDED RADAR IMAGERY

J. Holtzman, F. Dickey, and T. James
NASA

Both visual interpretation of radar imagery and analysis using densitometric data extracted from radar imagery are influenced by

the photographic parameters of the recording process. The purpose of this effort is to specify the relation between the radar signal and the film optical density in terms of the parameters of the film system.

Included in the study was the development of a relation for correcting antenna pattern error effects in the image.

RADAR IMAGE QUALITY

J. Holtzman and F. Dickey
NASA

This program is a parametric study utilizing imagery, scatterometer data and octave-bandwidth trometer data to determine the effect of polarization, frequency, incidence angle, look direction, dynamic range and resolution on image quality and data content.

This effort is expected to provide new and expanded data on relative backscatter of targets. Also being investigated is the target related information in the properties of the radar image speckle pattern.

RADAR HOLOGRAM PROCESSOR

J. Holtzman and F. Dickey
NASA

Holographic recording of synthetic aperture imagery provides a dynamic range capability much greater than that of conventional photographic storage. The use of holographically recorded imagery requires a relatively sophisticated optical system.

Basic analyses and studies necessary for the procurement and use of the optical system have been completed with procurement pending in the near future.

The optical system will be used to provide a source of high-resolution large-dynamic range synthetic aperture imagery for evaluation with respect to remote sensing applications. The output imagery will be used by both geographers and radar-system-oriented engineers as an input to remote sensing studies.

DIGITAL PROCESSING OF SYNTHETIC APERTURE RADAR

**Ralph Gerchberg, R. K. Moore, Fred Dickey,
J. Holtzman
NASA**

A proposed digital processor for a 1975 synthetic aperture spacecraft radar has been devised and its performance simulated on a general purpose computer. To obtain the averaging required to improve the gray scale rendition over that for a typical standard synthetic aperture system, the processor makes a trade-off between resolution and averaging. Separate portions of the available aperture are processed independently to achieve the equivalent of normal synthetic aperture images having poorer resolution than theoretically possible. The individual images are combined in the processor before being displayed, and the resulting averaged image is presented for display.

The use of subaperture processing and combination also makes a considerable saving in memory requirement relative to that for a fully processed fine resolution system. The proposed spacecraft radar uses ten subapertures, requires 4.8 megabits of storage, and is postulated to require about 200 watts. It produces a resolution of 30 meters with an antenna 4 meters long, and achieves a mean to standard deviation ratio of 4.3 for a Rayleigh distributed target, as contrasted with a ratio worse by the square root of 10, obtained without multiple subaperture processing.

The processor correlates the incoming signal with an appropriate point target reference signal. It is proposed to use LSI memories using CMOS semi-conductor technology.

RADAR SYSTEM ANALYSIS

**J. Holtzman and F. Dickey
NASA**

Remote sensing applications of radar introduce new systems analysis problems to be solved. There is much to be learned before the optimum radar system can be specified for a given remote sensing application. This investigation is directed toward performing the system and data analysis leading to criteria

for specifying imaging radar systems for use in remote sensing.

This effort is one of a continuing nature. Included in the study is the comparison of quadrature and non-quadrature radar system performance for a randomly distributed target. Quadrature systems were shown to have a superior mean to standard deviation ratio by a factor of 3 dB. The merits of real aperture and synthetic aperture systems are presently being investigated. Also, presently being considered are dynamic range and multi-polarization requirements.

RADAR SCATTEROMETER SYSTEM ANALYSIS

**G. A. Bradley, J. C. Holtzman, R. K. Moore,
and J. Young
NASA-MSC**

The analysis of radar systems used in remote sensing applications forms the basis of understanding and interpreting the experimental data measured by the available sensors. Through analysis of the operation of the radar system, it is possible to predict the performance of the radar, including the sensitivity of the system and the accuracy and validity of the measured data.

Understanding the capabilities and limitations of the currently available sensors is essential in the design of the experiments. In addition, the system analysis activities are vital to the design and development of new radars for the remote sensing application.

This study focused on the prediction of the performance of two radar scatterometer systems used in the NASA-MSC remote sensing program. The major purpose of these activities has been two-fold: first, the result of the analysis provides a capability for interpretation of measured data, and second, the analyses provide guidelines for operation and alignment of the systems and recommended changes in the system to improve performance.

Two radar scatterometer systems are used in the experimental programs sponsored by NASA-MSC. The first system is a vertically-polarized CW-Doppler system operating at a frequency of 13.3 GHz which measures the radar scattering coefficient for incidence angles

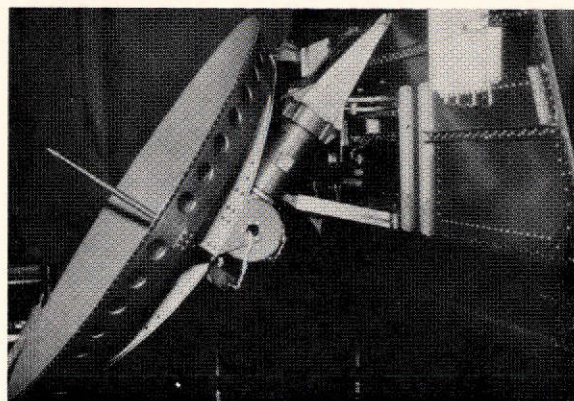
between $\pm 60^\circ$. The second system is similar, but operates at a frequency of 400 MHz and has dual-polarization capability. Measurements of the scattering coefficient using these two systems have been taken over the ocean surface, over agriculture terrain and over arctic sea ice. System analysis activities have included study of the sensitivity of the radars as a function of operating conditions, error analysis and analysis of the digital data processing requirements for the measured data. In addition, a thorough analysis of the data validity and accuracy has been completed. The results of these analyses have been used to improve the system operation as well as to tailor the design of the experiments to the capabilities of the radar scatterometers.

SKYLAB—S-193 RADSCAT DEVELOPMENT

R. K. Moore, W. E. Spencer, Walter Hanley,
and Arun Sobti
NASA

The NASA SKYLAB Program is developing an earth orbiting, manned satellite scheduled for flight in May 1973. Originally conceived as strictly solar oriented and, although well along in the development cycle, the Skylab concept was altered early in 1970 to include earth observation in several portions of the electro-magnetic spectrum. Five remote sensing instruments known as the Earth Resources Experiment Package (EREP) were added to the inventory of scientific equipment aboard SKYLAB. The EREP consists of a multi-spectral photographic system (S-190), an IR Spectrometer (S-191), an IR multi-spectral scanner (S-192), a Ku band microwave RADSCAT/altimeter system (S-193), and an L band microwave radiometer (S-194). Of these, the S-193 system development is the area of concern for the present contract. Dr. Moore originated much of the conceptual design of the S-193 RADSCAT system.

The S-193 is a composite device consisting of three essentially separate instruments; i.e., a radiometer, a scatterometer and an altimeter all operating at a frequency of 13.9 GHz and sharing a number of system components in time multiplex. The radiometer measures radiation which is self emitted by the earth's



SKYLAB microwave instrument (radiometer/scatterometer/altimeter) built by General Electric.

surface and is proportional to the surface radiometric temperature which is, in turn, related to the physical surface temperature through the surface emissivity. A radiometer itself provides only radiometric temperature data and no evidence of emissivity. The scatterometer is a radar system which measures σ° , the surface differential backscatter coefficient. Knowledge of the σ° factor allows the emissivity to be estimated. Further, the radiometric data can be used to estimate the condensed moisture content and thereby provide an attenuation correction for the scatterometer data. Combined use of a radiometer and a scatterometer over a given surface area derives more information about the surface characteristics than is possible with the instruments operated singly. Near-simultaneous operation of the radiometer and scatterometer is the basis for the RADSCAT mode of operation of the S-193. The instruments can also be operated individually where desired. The S-193 equipment is under development at the General Electric Space Systems Organization at Valley Forge, Pennsylvania.

The modes of operation of S-193 are keyed both to the type of instrument and to the type of scan that the antenna performs. The antenna develops a pencil beam which can be mechanically driven either perpendicular to the line of travel (cross track) or along the vehicle line of travel (in track). Further, the scan can be a continuous motion which senses areas of the earth's surface which are contiguous or touching (and in fact overlapping) or in discrete steps (from non-contiguous

areas). The many options available allow for considerable versatility in the use of S-193. Polarization diversity further adds to the versatility of operation.

Experimental studies at Kansas in collaboration with New York University using data from the NASA Earth Resources Aircraft Program experiments have demonstrated definite relationships between radar return and wind speed/wave heights at sea. A prime purpose of the S-193 system is to demonstrate the ability of a spaceborne RADSCAT system to monitor winds and waves on the world's oceans on a nearly continuous basis. The data sensed over land has application to many different disciplines such as hydrology, geography, geology and ecology.

The present contract is devoted strictly to the development, testing and integration of the S-193 into the SKYLAB system. The specific tasks involved include completing a comprehensive systems' analysis; providing technical assistance to NASA through representation at design and decision making conferences and performing special technical analyses as required; providing technical assistance during the various testing sequences plus evaluation and interpretation of test results; and studying detail of data processing requirements, display, and interpretation techniques to define the methods to be employed for optimum extraction of information from the SKYLAB data.

A COMPARISON OF METHODS OF ESTIMATING THE MEAN SQUARED SIGNAL

J. P. Claassen
NASA

Square law processors are often utilized to estimate the average power of a random signal. A good estimate of the average power requires that the output of a square law detector be averaged for a sufficient length of time. Typically, the average is performed by an analog integrator which integrates a continuous and, therefore, correlated signal. It is known that the accuracy in estimating the mean can be degraded when correlated samples are averaged.

As a consequence, a study was undertaken

to examine the degree to which the mean squared estimate of the signal is degraded by this integration method. The average power determined by averaging uncorrelated samples of the squared signal serves as a basis for comparison. In this study, the variance in the estimate of the mean power was computed for a narrow band gaussian-signal having a rectangular spectrum for various integration periods, T . It was shown that the variance of the estimate is dependent on the reciprocal of the time-bandwidth product, TB . The variance of the mean power estimate was then compared with that computed from averaging uncorrelated samples for the same period. This comparison showed that the accuracy in averaging a continuous signal suffers slightly, early in the integration period. The accuracies, however, are comparable once the integration period exceeds the time to average ten uncorrelated samples of the signal. The details of this study are available in CRINC Technical Memorandum 186-1.

MULTISPECTRAL HASSELBLAD CAMERA CLUSTER

D. D. Egbert, J. C. Barr, and R. K. Moore
NASA

The Remote Sensing Laboratory acquired four 70mm Hasselblad cameras in 1970 for the purpose of constructing a multispectral camera cluster. The camera cluster has been mounted in a University experimental aircraft and has been made available to several on-going projects during the past year for obtaining aerial photographs of specific areas. Several flights have been made and the multispectral photographs used for studies involving ecology of natural plant communities, watershed control, crop identification, urban land use, transportation networks, and tornado damage.

As a research tool the camera cluster has proven invaluable to many studies by providing timely aerial coverage of specific areas. For example, in the tornado damage study aerial photographs were taken immediately after the damage occurred before cleanup operations had disturbed the litter. Thus,

valuable information was obtained about the exact manner in which the damage occurred. Also, the natural-vegetation ecology study required repeated coverage of the same test site throughout the fall season as the vegetation was turning color and the trees losing their leaves. Different species turn color at different times; thus, temporally separated multispec-

tral photographs provide a means for mapping certain vegetation types.

A new mount has recently been designed to make the camera cluster more versatile by allowing it to be mounted on readily available Cessna 172 aircraft. Using the new mount and locally available aircraft, more distant test sites might be photographed.

DATA PROCESSING STUDIES

AN AUTOMATED IMAGE PROCESSING SYSTEM-IDECS (IMAGE DISCRIMINATION, ENHANCEMENT, AND COMBINATION SYSTEM)

R. K. Moore, G. L. Kelly, R. M. Haralick, and P. Anderson

NASA, U.S. Army, and Project THEMIS
monitored by the U.S. Army Engineer
Topographic Laboratories

The IDECS is an analog-digital near real-time image processing system which has been in continual development at The University of Kansas Center for Research, Inc., for several years. The IDECS is a unique facility for performing a wide variety of enhancements; measurements, and category discriminations on single and multiple images. Currently the input images must be in photographic form, but the source may be aerial or space photography, airborne radar, infrared, multi-spectral scanner, medical or industrial X-rays, or maps. The primary IDECS output is on a color display unit; however, other outputs include a black-and-white monitor, area measurements on a counter, and a pseudo three-dimensional display.

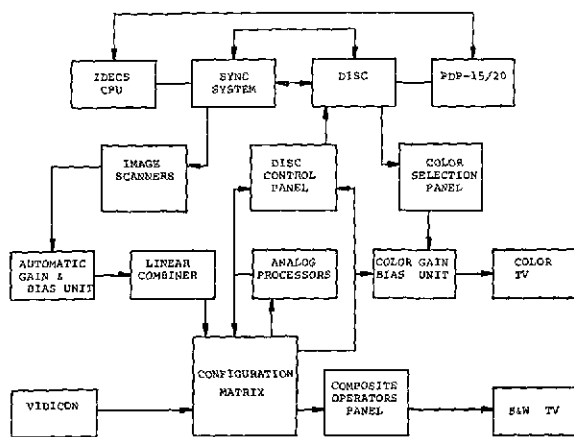
A block diagram of the IDECS is shown in the figure. Input to the IDECS consists of three flying-spot scanners capable of handling image transparencies from 4×5 inches to 35

mm format and a vidicon camera utilized for map or photographic inputs. A congruencing unit is used to rotate, translate, and scale images.

Once the images are congruenced, they may be processed and enhanced by the IDECS by choosing one of the available processing and enhancing functions. One function is a linear combiner unit which performs a linear transformation on the video signals of the flying spot scanners. The linear combinations of the multi-image set are performed in 1/30 of a second. This unit may be used for spectral-temporal coordinate rotation of the multi-image set if the coefficients of the linear transformation are selected appropriately.

Another function is level selection. A level selector produces a positive binary output for an image if the input video signal is between two adjustable thresholds and can be operator controlled or computer controlled. In addition, two or more level selectors can be logically combined producing an output if each one has an output, thus implementing a MIN-MAX decision rule.

The automatic discriminator is a unit (not computer controlled) used to select and display all points of an image whose grey tones fall within the same range of grey tones as



Block diagram of the IDECS.

those detected in a small rectangular training area of the image. The position of this training area is selected using a joy stick. Two additional controls are used to adjust vertical and horizontal size of the training area. To perform an automatic discrimination, a rectangular training area is first defined on the image. Peak detectors then sample and hold the maximum and minimum signal levels within the range of the training area. The remaining portion of the video signal is then compared with the peak levels of the training area. Whenever the video signal falls within the training voltage range a positive binary output is produced for processing, display, or transfer to the disc.

A digital disc having twenty-four channels and containing 2.4×10^6 bits of storage is shared by both IDECS and the PDP-15/20. The disc may be used to store binary images of the type produced by the IDECS level selectors and pattern discriminators or it may be used for limited storage of digitized images. The TV display units are synchronized to the disc and the entire contents of the disc can be transferred to the TV screen in the $1/30$ second frame rate. In addition, an interface between the disc and the PDP computer allows information transfer between the computer and the disc at a rate of 18×10^6 bits per second. Real-time digital logic is set up so that any logic operation can be performed between any two channels of the disc.

The video signals may be brought to the TV display screens in a variety of ways. Each image of the multi-image set, as well as dif-

ferentiated, level-selected or linearly combined images, may be displayed on the monitors. The multi-image set can also be linearly combined into three different linear combinations and the resulting three video signals may be used to drive the red, green, and blue guns of the color TV monitor to obtain a continuous tone color image. When the processed images have been stored on the disc by level selection or automatic discrimination, the color selector may be used to display the information in a discrete tone color image. Each channel of the disc can be assigned by the color selector to one of ten fixed colors and one of ten fixed textures. For each place on the channel that there is a positive binary output the chosen color-texture combination is produced at the corresponding location on the color monitor.

Another way of displaying information on the disc is by the fast digital to analog converters. One eight-bit digital to analog converter (DAC) can be connected to the black and white monitor and can be driven by eight channels of the disc, or three eight-bit DAC's can be connected to the color monitor and can be driven by 24 channels of the disc.

Other functions include a unit to measure the area of any displayed category or grey level, a variable time constant differentiation unit to enhance edges, and a pseudo three-dimensional display unit which permits viewing the three-dimensional surface generated by the grey-tone density of an image. Soon to be implemented is a near real-time ($1/30$ of a second) table lookup pattern discriminator which assigns categories on the basis of the digitized levels of two video signals and stored parameters for a discrete Bayes decision rule.

In addition, a PDP-15/20 computer has been interfaced to the system so that the IDECS can be program controlled and possess a wider capability in performing image enhancements and category identifications. The PDP has 12K of 18 bit word memory with an access time of 800 nanoseconds, a processor with integer multiply and divide, a paper tape reader and punch, a card reader and two DEC tape drives. The PDP-15/20 will perform the task of calculating statistics and issuing commands to the IDECS central processing unit (CPU). The CPU in turn will direct data flow and processing in the IDECS.

IDECS—PDP 15/20 COMPUTER INTERFACE

P. N. Anderson
NASA and U.S. Army

The IDECS central processing unit, CPU, shown in block diagram form has been attached to the system so that the PDP-15/20 computer can guide processing. Just as there is a flow of image-derived data in the system, there is also a flow of control-type data or messages. These messages flow from the PDP-15/20 to the CPU which decodes or extracts from the messages data which is passed on to the registers and converters controlling processing and enhancement subsystems. Thus, the CPU consists of two parts: (1) the interface between the PDP-15/20 and the IDECS, and (2) the controls necessary for directing the activities of the IDECS.

The interface selection logic controls the transfer of data that is passed between the PDP and the IDECS. The instruction register directs the activities in the CPU by utilizing data received from the PDP. The sample register (SR) gathers data from the IDECS and retains it until it can be sent to the PDP. A digital/analog converter is attached at the output of the register; with a comparator, a clock source, a gate, and the SR configured as a counter, the unit acts as an analog/digital converter. The digital signal resulting from an A/D conversion ends up in the SR. Thus, most analog signals processed by IDECS can be made available to the PDP computer through the multiplexor and sample register. Signals resulting from processing images in IDECS can be transferred to storage in the disc under computer control. In addition, manipulation of multiple images on the disc may be accomplished utilizing the disc operating panel. Twenty row registers and eight parameter registers controlled by the CPU determine the configuration of the IDECS system units for a particular experiment and the status of the processing circuits.

When the monitor or supervisory programming packages are completed, the IDECS and PDP will perform the pattern discrimination process. That is, the PDP-15/20 will perform the task of calculating the statistics and generating a decision rule from training data gathered by the IDECS. The IDECS CPU then will implement the resulting rule (in

near real-time) on data derived by scanning the images. In general, five steps will be required in performing category identification for images:

- (1) the images will be congruenced,
- (2) training data will be obtained by the computer from the images by directing the IDECS to scan appropriate areas,
- (3) from the training data, the PDP-15/20 will be programmed to determine the parameters for the chosen decision rule,
- (4) the calculated parameters will be used to set control voltages in the analog processing subsystems in the IDECS, and
- (5) the specified category identification will be made and displayed on a color monitor by IDECS.

COMPUTER CONTROLLED SIGNATURE SELECTOR

T. Polcyn and P. Anderson
U.S. Army

A level selector produces a positive binary output for an image if the input video signal is between two adjustable thresholds. The unit can be manually or computer controlled. In addition, two or more level selectors can be logically combined, called a signature selector, producing an output if each one has an output. Thus the unit implements a MIN-MAX decision rule. In other words, the output of the signature selector, D_i , is the AND of each of the level selectors where each output

$$D_i = \begin{cases} 1 & \text{if } V_{Li} \leq V_i \leq V_{Hi} \\ 0 & \text{Otherwise} \end{cases},$$

V_{Li} is the low threshold voltage, and V_{Hi} is the high threshold voltage. Under computer control the one volt range of threshold voltages can be set in increments of $1/256$.

IDECS DISC OPERATING PANEL

P. Anderson and J. Lubert
NASA and U.S. Army

A disc operating panel (DOP) is provided to control the transfer of information between

the IDECS and the disc storage unit. The unit can be manually or computer controlled. The panel and its circuitry is divided into three general parts: single channel recording and display, multichannel grey-level display, and synchronization. Synchronization signals from either the disc unit or an internal crystal circuit are available.

The first eight channels of the disc can be displayed in 4, 8, 16, 32, 64, 128 or 256 grey levels utilizing digital/analog converters in the DOP. Also, using a high speed analog/digital converter in the image scanner cabinet, an image can be digitized into sixteen grey levels and stored with a four bit code on the first four channels of the disc. This information is then decoded and displayed in color through sixteen channels of the color switching panel on the IDECS. Selected algorithms that allow manipulation of any two channels of the disc are also available on the panel.

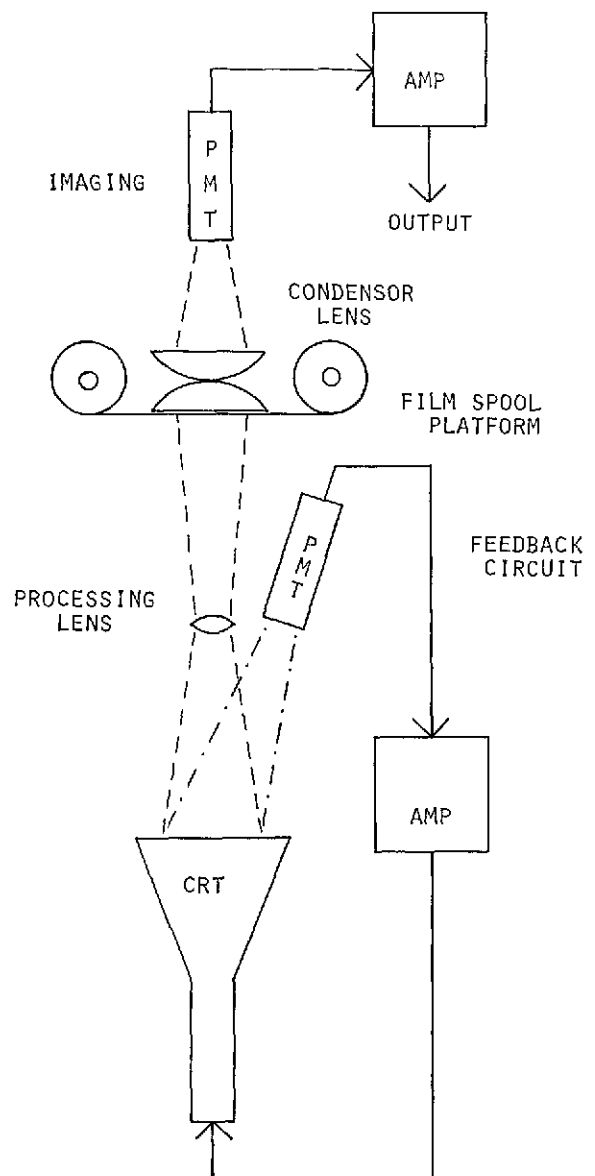
Disc channels may be displayed on any IDECS monitor through the IDECS configuration panel. A direct display mode is also available that allows viewing the output of the level selectors, automatic discriminator or light pen through the DOP.

IDECS FLYING-SPOT SCANNERS

P. Anderson, T. Polcyn and J. Barr
NASA and U.S. Army

Synchronous flying-spot scanners are the primary input device of imaged data for the IDECS. They are capable of handling any transparent image from a 35 mm to a 4×5 inch format. A scanner is shown diagrammatically in the figure.

A photographic enlarger stand has been adapted to provide the necessary adjustment of the relative positions of the processing lens and image plane which allows magnifying or demagnifying of the cathode-ray tube (CRT) raster to conform to various image sizes. The light passing through the images is collected by a condensor lens pair and focused onto a photomultiplier tube (PMT). The PMT output signal is then amplified and sent to the



The IDECS Flying-Spot Scanner.

IDECS for processing. A feedback (AGC) circuit is provided to insure uniform light intensity output of the CRT.

Three different scanning methods are provided with the combined PDP-IDECS-Scanner interface. A continuous scan, similar to a television raster scan, is the normal scanning method. Also available are a dot scan driven by digital/analog converters and a computer driven spot scan that are used in special applications such as generating histograms from images.

KANDIDATS

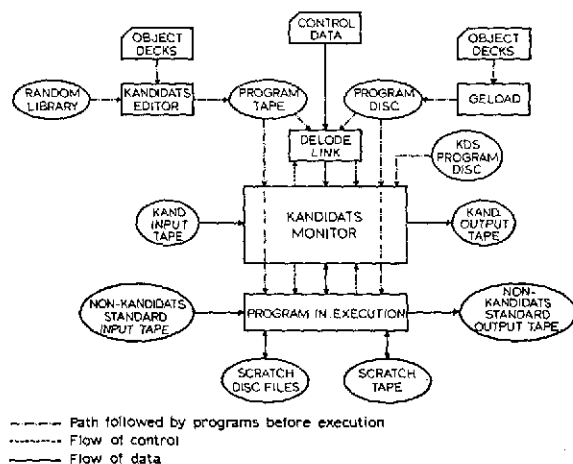
R. M. Haralick, G. Gunnels, G. Reynolds,
and M. Afarani

NASA and Project THEMIS monitored by the
U.S. Army Engineer Topographic Laboratories

KANDIDATS (Kansas Digital Data System) is a software package of multi-image processing programs designed to run on a GE-635 computer. KANDIDATS has the equipment and programming for the following operations: image digitization, texture analysis, congruencing, dimensionality reduction, quantization, feature extraction and clustering, and Bayes decision rules.

The above software package will be set up and controlled by the KANDIDATS monitor. The monitor is designed to minimize the cost of processing a set of data by speeding up I/O time and the overlapping I/O time with execute time. The monitor also handles all book-keeping operations which makes use of the routines very easy. It is easily expandable to allow the addition of new image processing programs.

KANDIDATS - BASIC SYSTEM



ADAPTIVE PATTERN RECOGNITION SYSTEM

R. M. Haralick and I. Dinstein
NASA

The best utilization of remote sensing technology for the earth applications area requires that large amounts of data be quickly classified. The sensor-environment which generates these data is subject to slow random fluctuations due to sensor drift or gradual

environmental change. Further, the categories of classification used by earth scientists may not match the kinds of categories the sensor sees and is capable of distinguishing. The usual statistical approach to classification has problems, since decision boundaries in measurement space will change with the slow random fluctuation. Work to find the natural categories which are associated with various environment sensor combinations is yet to be done.

The method of adaptive pattern recognition can provide an attractive solution to these earth applications problems. By learning the natural classification structure of the environment, the adaptive pattern recognition scheme can simplify the data and describe it in its most natural language. By continually adapting on new data, the adaptive pattern recognition scheme can preserve the natural classification structure in the background of the slow random fluctuation. This adapting behavior occurs in an unsupervised manner so that no operator intervention is necessary. It is ideal for automatic data processing.

MULTI IMAGE CLUSTER ANALYSIS

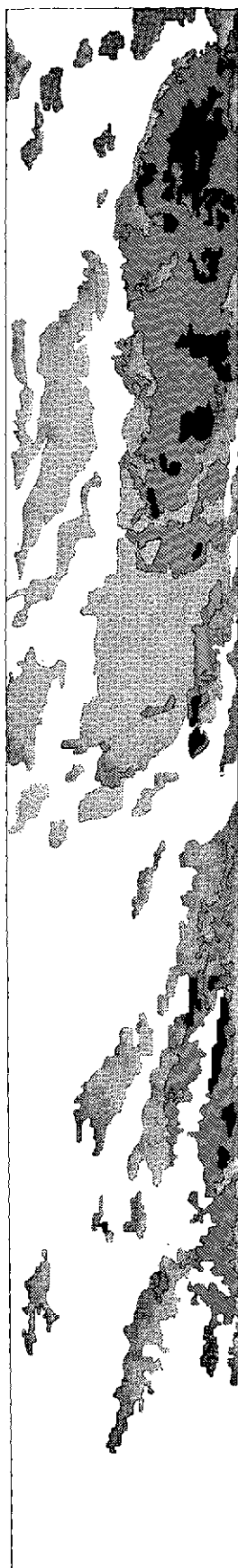
R. M. Haralick and I. Dinstein
USGS and Project THEMIS monitored by the
U.S. Army Engineer Topographic Laboratories

There are two basic ways of processing image data: (1) assigning each data point to a category from a given set of categories, and (2) assigning each data point to a cluster where the clusters are the natural data categories. Several cluster analysis programs designed for sequential data such as imagery have been developed. The output of these programs is a map indicating the spatially connected homogeneous regions in the multi-image data set.

TEXTURE TONE STUDY

R. M. Haralick
Project THEMIS monitored by the U.S. Army
Engineer Topographic Laboratories

Two fundamental pattern elements used in the human interpretation of pictorial data are texture and tone. The concept of tone is



based upon the varying shades of grey of resolution cells in a photographic image, while texture is concerned with the spatial distribution of the grey tones. Generally, texture is an innate property of virtually all surfaces—the grain in wood, the weave of a fabric, the pattern of crops in a field, etc. It carries important information concerning the structural arrangement of surfaces and their relationship to their surrounding environment. Although quite easy for a human observer to recognize and describe in empirical terms, texture has been extremely refractory to precise definition, and as might be expected, to analysis by digital computer. Consequently, while texture analysis would appear to be a profitable approach to take in attempts to automate photointerpretation, the difficulty in constructing even rudimentary processing algorithms has severely curtailed its use.

The texture tone study attempts to define texture by determining from any given image a nearest neighbor spatial grey tone matrix. For each angle and distance, the $(i, j)^{th}$ element of this matrix indicates the frequency with which grey tone i occurs at given angle and distance from grey tone j . Various statistics computed from this matrix then become the analytical textural features. A decision rule based around these features then enables an identification of the image on the basis of the texture tone information in the image.

MAKING PICTURES WITH A DIGITAL COMPUTER PRINTER

R. M. Haralick

Project THEMIS monitored by the U.S. Army
Engineer Topographic Laboratories

Anyone who has tried to use the printer on a digital computer to produce pictures has

A MAP OF CLUSTERS

Using ground truth supplied by a previous study, a correspondence was made between the clusters and the true ground categories. The white area corresponds to bog, forest, or cloud shadow. The bogs are moist areas with a lush growth of sedges and grasses. The forests are lodgepole forests and Douglas fir. The cross-hatched area corresponds to glacial kame. These are meadows underlain by sand and gravel and vegetated by grass and sagebrush. The diagonally striped area is glacial till. These are grassland and sagebrush meadows underlain by glacial till. Mixtures of silty to bouldery mineral soil is exposed over one-fifth of the area. The black area is bedrock exposure. It consists mainly of unvegetated bare bedrock exposed by glacial and stream erosion.

experienced the frustration of determining a character set which gives good even grey tone renditions. The problem becomes difficult; digital printer characters are originally designed so that they all have about the same blackness, and there is no methodology to finding a good character set except by trial and error.

The following criterion has been used to judge the grey tones created by any character set. Suppose there are N grey tones g_1, g_2, \dots, g_N arranged from lightest to darkest. A set of $N-1$ squares of grey tones are made, the i^{th} square has grey tone g_{i+1} in the inside and grey tone g_i on the outside. A judgment is made as to whether the ratio of darkness of the inside square to its background is the same on each square. Corresponding adjustments to the character set are then made.

<i>Grey Tone</i>	<i>Character</i>
1	half dot (a dot is printed with probability $1/2$)
2	.
3	,
4	:
5	+
6	=
7	+(
8	X.
9	X=
10	M=.
11	TN(
12	MWS
13	MW\$*

Illustrates the character set used to obtain 13 grey tones from a GE-635 printer.

OPTICAL DATA PROCESSING FOR SPATIAL FREQUENCY ANALYSIS

D. D. Egbert and F. T. Ulaby

Project THEMIS monitored by the U.S. Army Engineer Topographic Laboratories

The optical data processing bench is a recent addition to the Remote Sensing Laboratory and is located in the Space Technology Laboratories. The processor is used for spatial frequency and texture analysis of remote sensing images including aerial photographs, spacecraft photographs, and radar images. The processor can also be used for image enhancement. A recent study with bone X-rays revealed the presence of a hairline fracture previously undetectable to the radiologist. A study is under way now to use textural information derived from radar imagery to map natural vegetation.

Spatial frequency analysis yields valuable information about the size, directionality, and periodicity of the texture of a ground object as seen from the air. Before the advent of the laser and the development of optical processors, spatial frequency analysis was very difficult and time consuming. The optical processor provides spatial frequency data from an image almost instantaneously because of the natural relationship between the Fraunhofer diffraction pattern produced by the processor and the Fourier transform. Experiments are being designed which will convert the frequency data obtained from the optical processor into a form that will be compatible with computer pattern recognition programs providing an additional parameter for automatic classification and pattern recognition computer techniques that has not been available in the past.

GEOSCIENCE APPLICATION STUDIES

THEMATIC LAND USE MAPPING WITH SPACECRAFT PHOTOGRAPHY IN THE DALLAS-FORT WORTH AREA, TEXAS

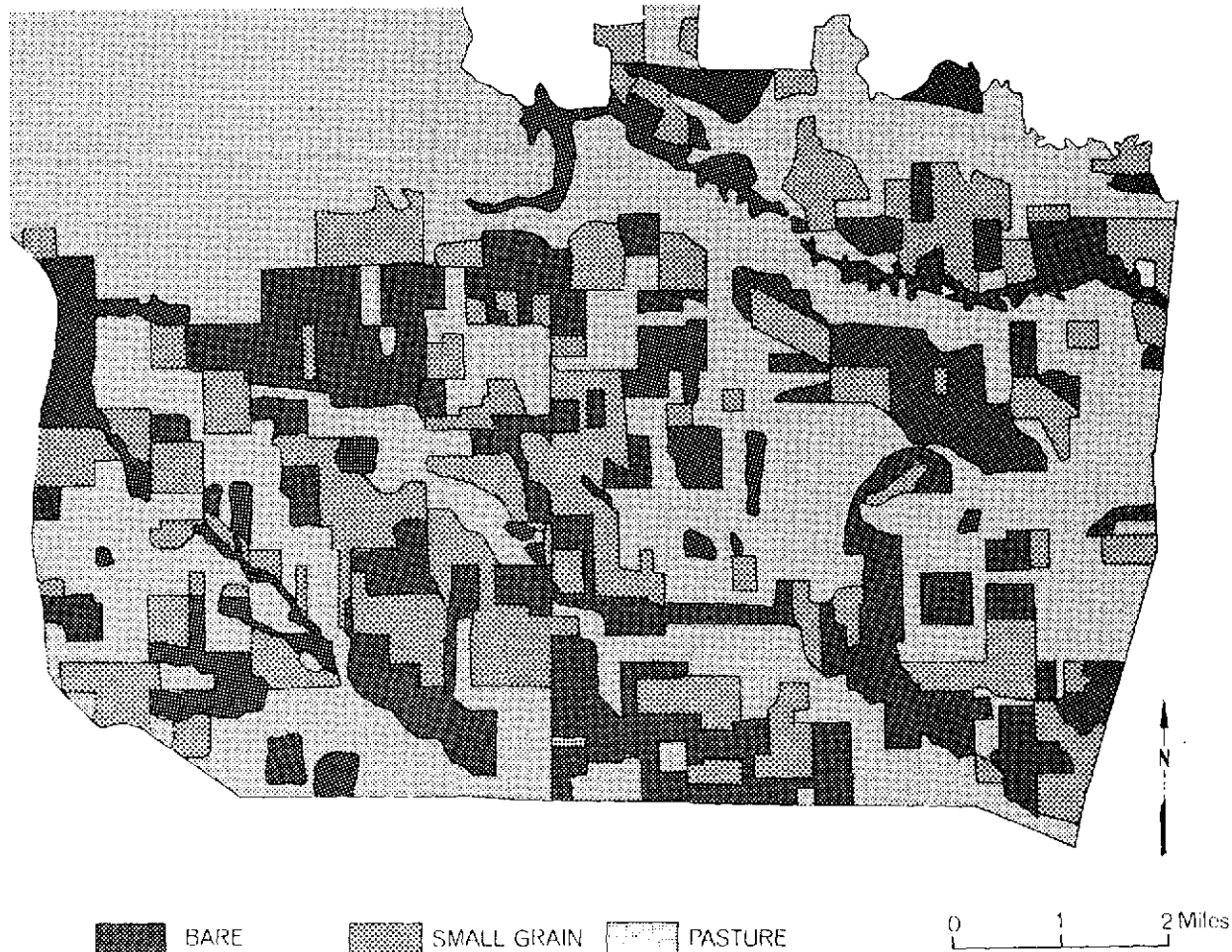
D. S. Simonett, F. M. Henderson, G. F. Jenks,
and J. R. Ratzlaff
U.S. Geological Survey

A preliminary study of two photographs obtained from the Apollo IX Mission of March, 1969, was completed to determine the degree to which these photographs could be used for land use mapping in the Dallas-Fort Worth Area, Texas. The first photograph was

normal color and had an areal weighted average resolution of about three hundred feet. A color infrared photograph from the SO-65 experiment of Apollo IX which had an areal weighted average resolution of more than 400 feet was selected as the second photograph. Both were taken of the same rural area near the Dallas-Fort Worth metropolitan complex.

The color infrared photograph was selected for greatest attention since its range of colors depicting land uses was wider than that of the normal color photograph. From this

Land Use in Rhome-Justin Test Area as Interpreted from Space
(Apollo 9 CIR Photograph), March 1969



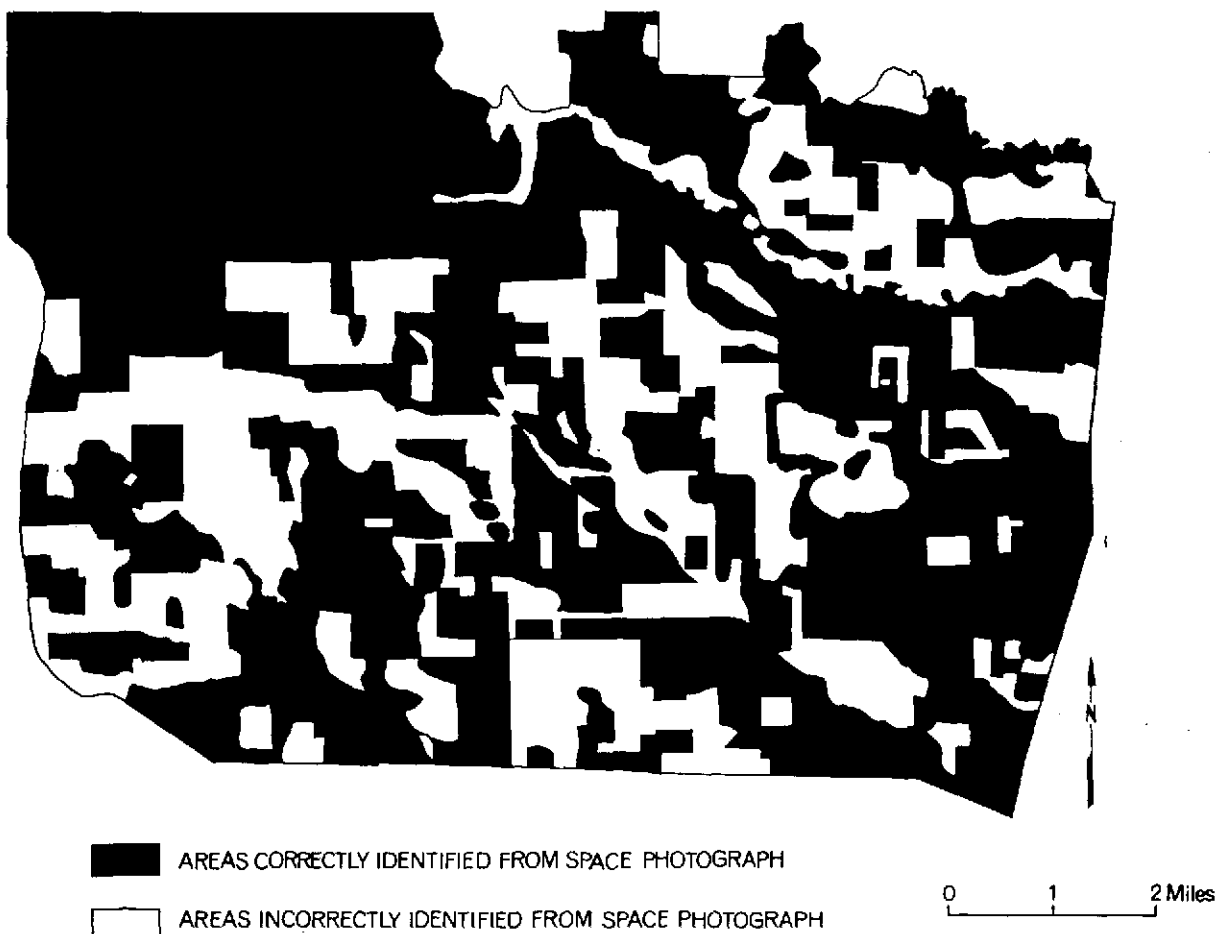
photograph and field work observations, a cloud-free study area, centered in the photo and offering a variety of land uses, areally extensive fields, and contrasting colors was selected for initial interpretation. A grid pattern of 40 acre cells was created and hues on the color infrared photograph were coded as nearly as possible to National Bureau of Standards' standard color chips. Selected fields representative of these colors were picked as base fields of "true" color for reference to other fields in coding and coloring the forty acre cell land use maps. However, the completed map contained too many colors and lumping into broad groups corresponding to land use was necessary.

Four smaller areas within the larger original study area were then selected for analysis in two steps: (1) on a 40-acre cell basis, and (2) on a field to field comparison.

Results using 40-acre cells were both significant and encouraging considering the system resolution. A cell was considered as having the land use that occupied the major portion of that cell. For this reason and since it was difficult if not impossible to identify field borders by this method, a field to field comparison was next completed but the results were disappointing.

Following these 40-acre land use cell discriminations, a decision-cell/resolution study on four sample air photographs within the

Comparison of Actual Land Use versus Land Use
Interpreted from Space Photograph
(Rhome-Justin Test Area)



four study areas was carried out to explore the relationship between decision cell and/or resolution cell size and the number of categories contained per cell. It was found that with the exception of the large blocks of pasture all the Dallas-Fort Worth rural and rural-urban areas fitted into the most complex spatially-mixed environments (level of complexity groups 7, 8, and 9) discriminated by Simonett and Coiner (1970) in their 100-case study of sample photographs throughout the United States rural districts. These results confirmed earlier judgment based upon the speckled and inchoate appearance of much of the area on enlargements of the color space photographs, that the resolutions actually employed in these color and false color photographs of the Dallas-Fort Worth Area were inadequate to affect a proper discrimination of the environment. Resolutions of the order of 100 feet would in fact prove to be necessary for effective thematic land use mapping in this area, although resolutions of 200 feet would be a distinct improvement over those actually obtained in the Apollo IX photographs.

SNOWFIELD MAPPING USING IMAGING RADAR

H. C. MacDonald and W. P. Waite

NASA and Project THEMIS monitored by the U.S. Army Engineer Topographic Laboratories

Permanently mapped snowfields in the high mountains and spring snow that has been on the ground all winter in the St. Lawrence Valley both seem to give quite strong radar return at 8.6 mm wavelength, whereas relatively new and dry snow is penetrated and gives little return other than that from the underlying ground and vegetation. Characteristic of the return from the old snow is its relative independence of angle of incidence. Thus, the snowfields mapped were almost isotropic scatterers. This suggests that the phenomenon responsible is volume scatter rather than any kind of surface scatter.

A comparison of the radar return from glaciers and that from the old snow indicates very little signal coming back from the glacier relative to that from the old snow. Thus, the radar image may be used to differentiate the

snowfield from the glacier, even though both may look the same on a photograph if the glacier has a thin coating of dry snow.

The impact of this study on hydrologic forecasting may be quite considerable. At present, the results are still qualitative. We look forward to quantitative experiments.

SOIL MOISTURE DETECTION WITH IMAGING RADAR

H. C. MacDonald and W. P. Waite

NASA and Project THEMIS monitored by the U.S. Army Engineer Topographic Laboratories

A study of radar imagery obtained with a real aperture system near Baton Rouge, Louisiana, indicates the significant correlation between soil moisture and radar images. In particular, the moisture pattern in the soil was shown to be very important at relatively steep incidence angles, whereas at incidence angles closer to grazing, the main determinant of the radar return appeared to be vegetation. The cross-polarized return appears to be dominated by vegetation effects at all angles of incidence. The vegetation during the study was defoliated since the imagery was obtained in the middle of winter. Presumably, summer vegetation in this area might obscure the soil moisture return at all angles of incidence; on the other hand, use of a longer wavelength imager than the 8.6 mm system of the study probably would permit soil moisture determination even in summer.

SOIL TEXTURE AND MOISTURE MONITORING WITH RADAR

S. A. Morain and J. C. Campbell

NASA









Soil texture and moisture, under certain circumstances, are susceptible to detection by active microwave sensors. The most useful sensor parameters relating to backscatter (σ^0) from soils are: (1) frequency, (2) polarization, and (3) angle of illumination. The primary soil characteristics contributing to backscatter are: (1) soil texture, which, as it varies from clay through boulder categories, varies

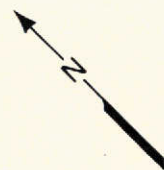
Soil Boundaries Northwest of Tucson, Arizona (derived from K-band SLAR)



LEGEND

0 3 Km
0 2 Mi
Scale

 Broken and stony land	 Loam	 Clay loam
 Sandy loam, stony phase	 Fine sandy loam, loamy fine sand	 Agricultural land
 Sand, Gravelly sandy loam	 Silt loam	



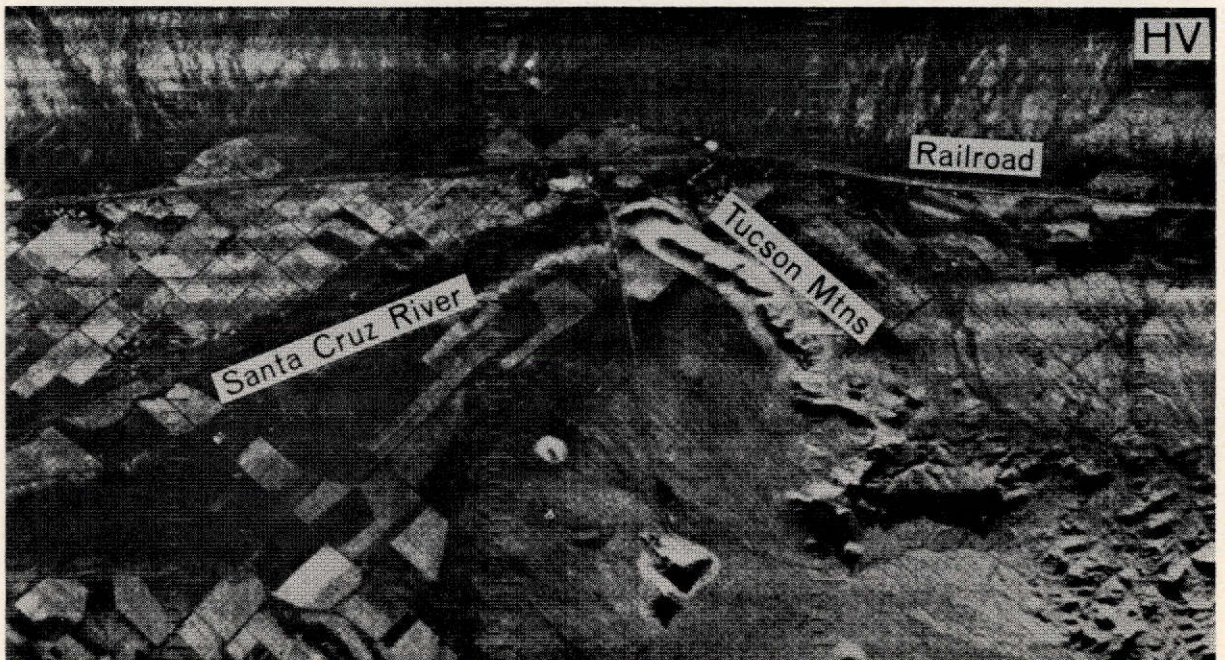
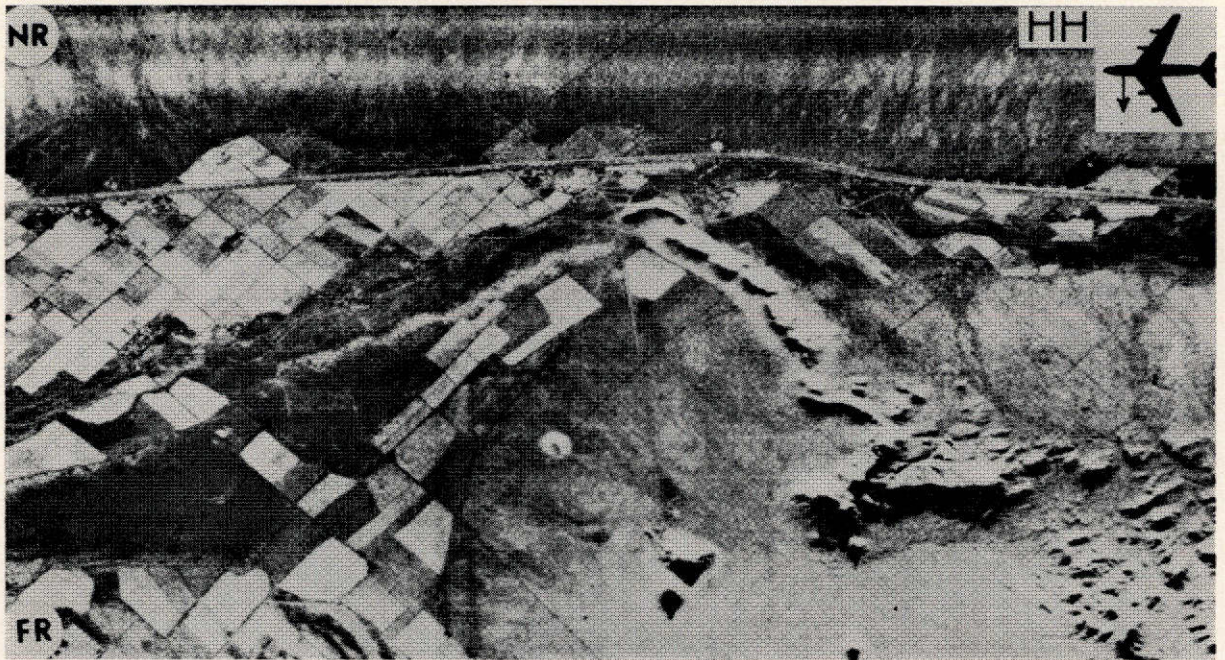
Categories simplified from: Soil Survey of the Tucson Area, Arizona, 1931

SAM/CRES/70

in surface roughness and thus influences the amount of backscatter; and (2) soil moisture, which alters electrical conductivity of the soil, thus influencing the depth of signal penetration and the amount of re-radiation. In theory, low frequency radar (L-band) should best be able to detect boulder surfaces (assuming a flat, dry, surface free of vegetation and of uniform roughness) and higher frequencies (V-band) should be sensitive to soils comprised of medium sand. Analysis of AN/

APQ-97 SLAR imagery of an area near Tucson, Arizona, produced soil texture groupings which corresponded well with existing soil maps.

Moisture effects are most pronounced at steep depression angles (low angles of incidence). Thus, at low frequencies and steep angles, ambiguities could arise between returns from dry boulder surfaces and moist loamy surfaces. At shallower depression angles, however, moisture effects can combine



K-band radar imagery near Tucson, Arizona. Note soil patterns revealed on alluvial fans surrounding Tucson Mtns. and on slopes north of railroad line. Pattern in valley is partly obscured by agriculture.

with vegetation to yield higher than expected backscatter. SLAR imaging of soil moisture was demonstrated using imagery of Hutchinson, Minnesota, in which some areas of peat and muck soils imaged strongest, especially in the near range. SLAR's advantages as a

remote sensor (large area coverage, adequate resolution from space altitudes, all weather operation) combined with potentials for imaging soil properties, such as texture and moisture, should make it a useful tool for earth resource inventories in the 1970's.

GEOMORPHIC EVALUATION OF RADAR IMAGERY OF SOUTHEASTERN PANAMA AND NORTHWESTERN COLOMBIA

Anthony J. Lewis
U.S. Army

The purpose of this study was to evaluate the potential of radar imagery for use in geomorphic analysis using southeastern Panama and northwestern Colombia as the test site.

Many regions in the world are poorly mapped or totally unmapped because of the inability to obtain aerial photography as a result of light limitations and weather conditions. Unlike many remote sensing techniques, radar has the capability of recording terrain data irrespective of most weather conditions and totally independent of solar illumination.

The Darien Province of the Republic of Panama was selected as a test site as portions of this province had never been mapped because of the perpetual cloud cover and limited accessibility. The region contains a variety of terrain ranging from seacoast and swamps to mountains at the continental divide.

The airborne acquisition equipment was contained in a YEA-3A type aircraft. The primary sensor used was the AN/APQ-97 side-looking radar, a K-frequency band, real aperture radar with three-axis stabilization of the antenna. An AN/APN-96 doppler radar was added to the aircraft to provide drift and ground speed information. The radar imagery with delineated control was inserted into an electronic sketching device for transfer of planimetric detail onto a map base.

Program objectives which were studied included: (1) Determining the overall feasibility of producing topographic maps from medium resolution side-looking radar presentations; (2) Establishing concepts and techniques for radar mapping data reduction and compilation; (3) Determining the performance characteristics of state-of-the-art radar equipment in a near operational environment; (4) Obtaining original mapping coverage over a geographic area with a known history of continually inclement weather.

Interpretation of the imagery obtained has allowed the definition of certain capabilities and limitations related to geoscience analyses as well as resulting in a topographic map of

Darien Province. The geoscience data available on the Panama imagery far exceed the terrain information previously available. When supplemented by corroborative ground truth data, radar remote sensing offers the only practical technique for terrain analysis in cloud-shrouded inaccessible environments such as those found in Panama.

VEGETATION MAPPING WITH SIDE-LOOKING AIRBORNE RADAR: YELLOWSTONE NATIONAL PARK

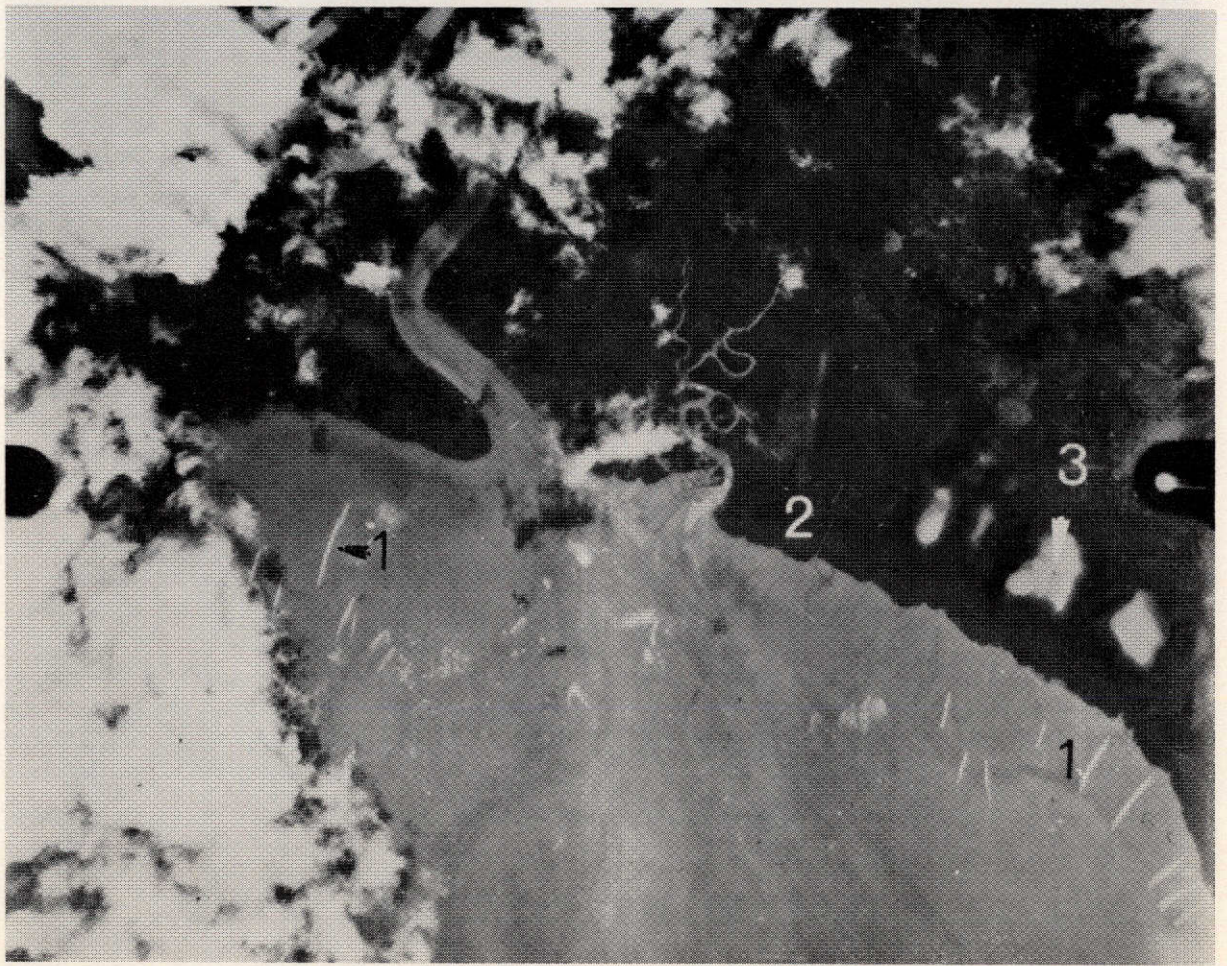
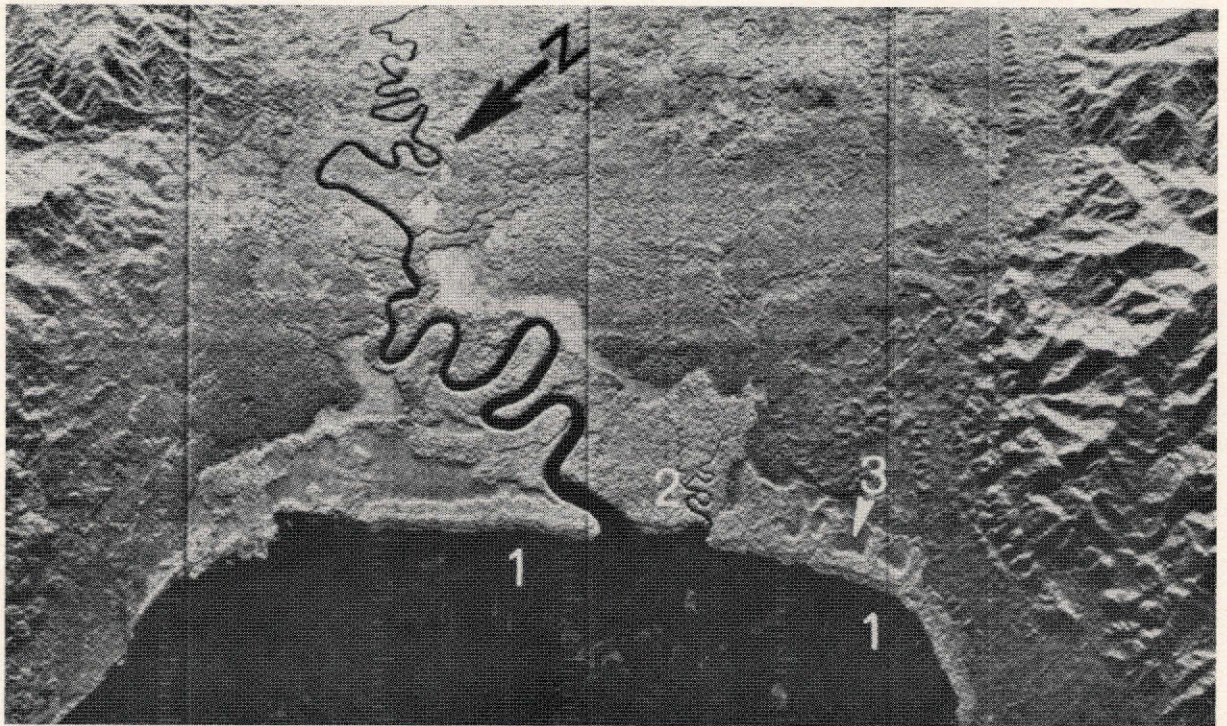
N. E. Hardy
NASA

This study delimited the vegetation communities of Yellowstone National Park to the greatest possible extent by interpreting SLAR imagery and identified factors which could be modified or controlled to enhance information content for any future SLAR vegetation mapping projects.

The plant communities of the park are structurally fairly simple and conform to those typical of the eastern Rocky Mountains. The main dryland sagebrush species in the area is *Artemisia tridentata*, although at least two other species play a lesser role in the make-up of the communities.

The interpretation approach to the SLAR imagery was first to define the boundaries of the vegetation communities. After boundary definition, classification of vegetation types was established based upon elevations, moisture and slope features evident in the SLAR image. The boundaries which were determined from the imagery corresponded well with those shown on the ground truth map. However, the vegetation classification derived from the imagery was not in total agreement with that shown in the ground truth map. To assist in the classification of the vegetation communities, a matrix interpretation key was constructed.

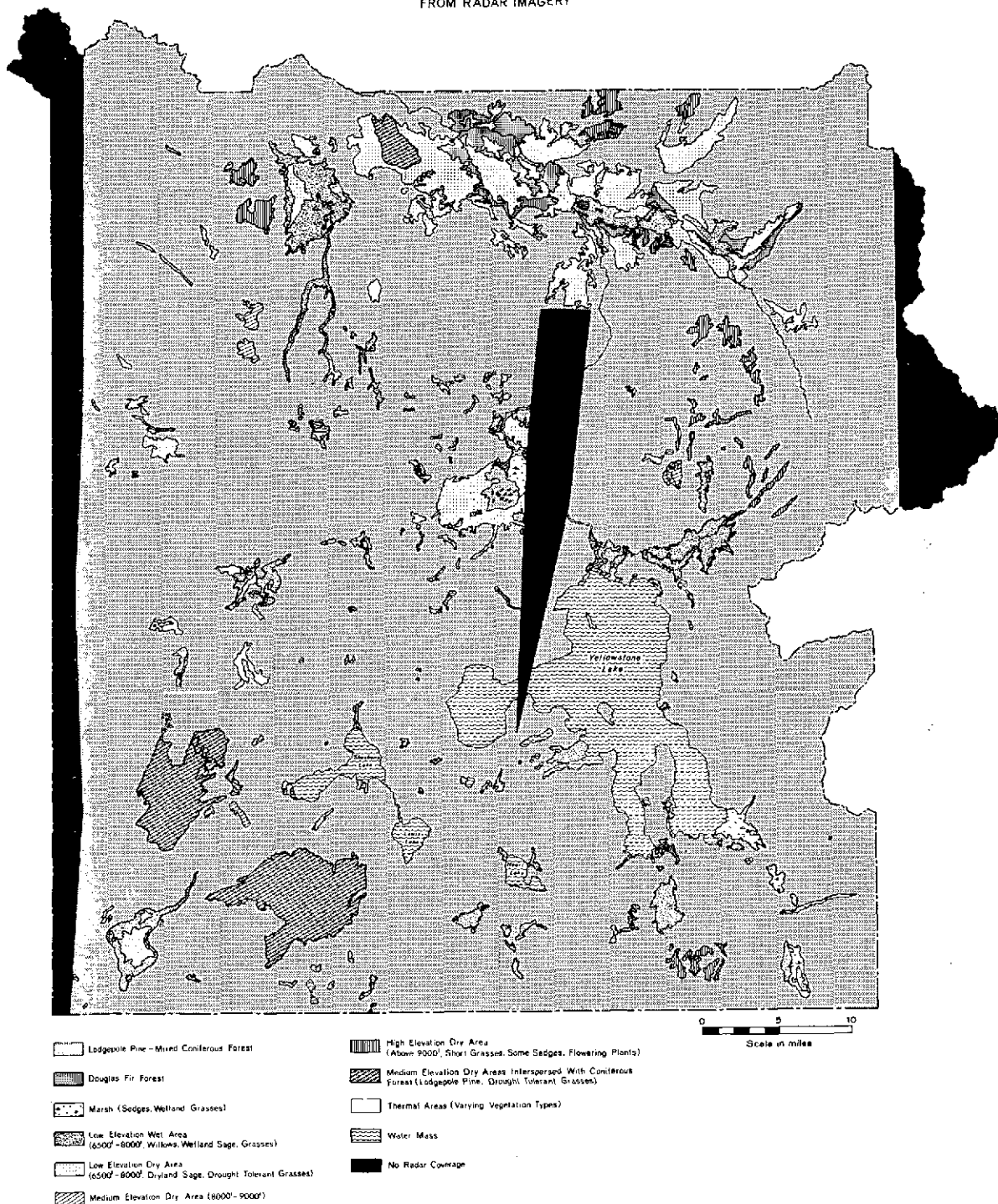
Comparison of the vegetation map developed from SLAR and that prepared from ground truth data points to the ability of an active microwave image to provide vegetation information at the community level. The maps provide a basis for evaluating SLAR's



Radar imagery (top) and aerial photograph (bottom) of shell reefs (1), mangrove (2), and non-vegetated areas associated with semi-dry mangrove coasts (3) east of Garachine in San Miguel Bay, Panama.

VEGETATION

YELLOWSTONE NATIONAL PARK
FROM RADAR IMAGERY



ability to consistently generalize recognizably significant vegetation communities. This study points to the potential importance of SLAR in the mapping and analysis of the

plant communities in less accessible areas of the world and defines mission planning measures which can increase the information content of the SLAR imagery.

RADAR GEOLOGY

Louis F. Dellwig, Harold C. MacDonald,
Richard S. Wing, James R. McCauley
NASA, U.S. Bureau of Mines, and Project
THEMIS monitored by the U.S. Army
Engineer Topographic Laboratories

Emphasis in geological research continues to be placed on the evaluation of radar relative to other sensors and the understanding of the targets' responses to the impinging radar beam. In most cases geologic data, necessary for sensor evaluation, constituted an important contribution in its own right.

Projects were varied; however, all were approached with the single aim of developing techniques for sensor utilization and data interpretation by the geologic community.

Specific objectives:

- I. PANAMA
 1. Evaluation of importance of look direction.
 2. Understanding of global tectonics in the Panamanian Isthmus.
 3. Utilization of SLAR for terrain analysis.
- II. BURNING SPRINGS, WEST VIRGINIA
Utilization of SLAR imagery for lineament analysis and detection.
- III. WESTERN U.S.
Utilization of SLAR for snowfield mapping.
- IV. GULF COAST
 1. Soil moisture detection with SLAR.
 2. Understanding of vegetation penetration.
- V. VIRGINIA DALE, COLORADO
Regional structural analysis with SLAR imagery.
- VI. PISGAH CRATER, CALIFORNIA
Effect of frequency variation in geologic studies.
- VII. CHOLAME AREA, CALIFORNIA
Utilization of radar for fault and fracture detection.
- VIII. WESTERN U.S. VOLCANIC FIELDS
Significance of anomalous cross-polarized return.
- IX. SOUTHEAST MISSOURI
Detection of new and extension of known mineral deposits.
- X. OUACHITA MOUNTAINS
Utilization of high-resolution radar in geologic studies.

With the exception of three studies the existing data have been fully utilized and the studies have been terminated. Evaluation of high resolution radar, evaluation of anomalous cross-polarized returns, and the study of the effect of variation of frequency continue.

RADAR USES FOR NATURAL RESOURCES INVENTORIES IN ARID ZONES

S. A. Morain
NASA

Although it is believed that imaging radar systems will serve an ancillary role to photography in remote sensing of desert environments, the scope of their usefulness should be closely reviewed. Normally the atmosphere over arid lands is cloud free and contains little moisture, hence photographic sensing in both the visible and infrared spectral regions is greatly enhanced. Spectacular photographs obtained by Gemini and Apollo spacecraft over the Sahara, the southwest United States and Australia testify to the potential of photography in acquiring resource data from these localities. Degradations result, however, from high albedos, which reduce contrast ratios; dust and haze, which reduce contrast and scatter short wavelength signals; color ambiguity, which confounds the task of terrain identifications; and earth-sun relations, which influence the quality of data received. Moreover, one should note that most arid lands are poorly known, remote, only partially photographed from aircraft altitudes, and very sparsely mapped. Under these circumstances, radar, employed simultaneously in space, might prove highly useful in landform inventories and studies of broad vegetational distributions. Other critical information pertaining to soil moisture variations, saline and mildly saline situations and certain geologic structures may be obtained. Lastly, the superiority of imaging radar to record continuous broad swaths of terrain should facilitate resource inventories by providing a preliminary, though non-metric, mapping base.

RADAR SENSING IN AGRICULTURE, A SOCIO-ECONOMIC VIEWPOINT

S. A. Morain, Julian Holtzman, and
Floyd Henderson
NASA

After a brief overview of radar signal-terrain interactions and an introduction to Great Plains agriculture, the meaning of both seasonal and year-to-year changes in image appearance between and within crops was in-

ACCURACY OF
CROP SEGREGATION ON SCATTERGRAMS
AS A FUNCTION OF RADAR FREQUENCY
AND DATE IN THE GROWING SEASON

Crop Type	7 - 66 Ka-Band %	9 - 4 - 69 Ku-Band %	9 - 15 - 69 Ka-Band %	10 - 69 X-Band %
Wheat	Not Present	--	--	--
Grafn Sorghum	82 (Cropped)	--	69	77
Corn		28	92	
Alfalfa		50	--	
Sugar Beets	92	--	97	64
Bare Ground	91	90	83	91

vestigated in terms of potential socio-economic benefits. As a means for obtaining crop statistics usable at several levels in the policy and planning hierarchy, a strategy for using dichotomous keys to identify crops from radar was prepared. An ability to monitor within-crop seasonal variations in image attributes (traceable as surrogates associated with crop calendar, yield, or quality) is regarded as most significant for the world's burgeoning population. Radar is beginning to demonstrate its range of applications in the Great Plains, and these applications were extended to world-scale monitoring tasks of such basic statistics as amount of land under cultivation and progress of regional harvests. Non-cyclic changes in crop backscatter as revealed through change detection strategies are regarded as useful, socio-economically, to ascertain diffusion rates and direction of crop introductions, adoption rates of agricultural innovations and similar man-land relationships. With the "Green Revolution" a controversial reality, the all-weather synoptic inventory capability of radar may be necessary in charting future food supplies.

MULTIBAND/MULTIDATE PHOTOGRAPH ENHANCEMENTS FOR AGRICULTURAL LAND USE

John C. Barr (University of Kansas);
D. T. Lauer and G. A. Thorley (University of California at Berkeley)

NASA and U.S. Army

IDECS (Image Discrimination, Enhance-

ment, Combination and Sampling) enhancements were prepared at CRING for a study conducted by the University of California to determine the usefulness of multiband photography of a test site in Imperial Valley, California, and multiband/multidate photography from an area near Mesa, Arizona, were analyzed to determine the effectiveness of the IDECS enhancements for crop identification. Results of the study indicated that the flexibility afforded by the IDECS system can be an effective aid in discriminating among agricultural crop types. In particular, the flexibility of data storage, retrieval, compression and display was aptly demonstrated in terms of color coding and discrimination of crops in the Mesa test area.

RADAR MONITORING OF AGRICULTURAL LAND USE: SOME PROBLEMS AND POTENTIALS AT THE LOCAL LEVEL

F. M. Henderson and S. A. Morain
NASA

Proponents of Side-Looking Airborne Radar (SLAR) systems have periodically analyzed the potential of this kind of imagery to identify crops. Yet, the agricultural landscape contains many other related phenomena that can be studied, if we are cognizant of them.

The complexities in land use practices affect crop variation and lead to observed differences in landscape patterns from region to region. It is obvious that the elements of the environment are so closely inter-related that an attempt to isolate the influence of one factor is extremely complicated. However, these environmental variables are not only problems but significant clues in analyzing and interpreting agricultural land uses from radar imagery. Some of the problems facing farmers and county agents in western Kansas were ascertained by conducting 112 interviews and recording user needs and perceptions. The result was a list and description of information desired pertaining to land use practices. In addition to crop identification, other information needed is often obtainable by SLAR.

THE STANDARD FARM: A TIME SEQUENTIAL DESIGN FOR CONTROLLED PARAMETRIC RADAR EXPERIMENTS IN AGRICULTURE

J. Holtzman, S. A. Morain, W. O. Lockman,
and P. L. Jackson
NASA

With the eventual goal of determining agricultural crop yields from radar imagery, the Standard Farm project involves individual controlled parametric experiments with radar system components on agricultural situations at the Garden City, Kansas, test site.

Large fields with high quality crop characteristics are selected at each flight interval to provide a model called the "Standard Farm." This model should provide the means for holding agricultural conditions constant while varying radar parameters.

The imagery parameters include Ka-, Ku-, X-, and L-band frequencies, three incident angles, and four polarizations. Each is individually correlated through time with agricultural characteristics such as crop type, row direction, crop height, and ground cover.

To date, Standard Farms have been selected for Westinghouse AN-APQ 97 Ka band and NASA DPD-2 Ku band imagery. The image densities of the selected fields have been digitized, and that information quantitatively arranged in histogram form. The data are now being evaluated to ascertain optimum sensor terrain configurations in the design of an agricultural radar.

AGRICULTURAL CROP DISCRIMINATION WITH COLOR INFRARED PHOTOGRAPHY: A STUDY IN DOUGLAS COUNTY, KANSAS

W. G. Brooner
U.S. Geological Survey

This study considered the feasibility of discriminating agricultural crops in Northeastern Kansas, using late July color infrared aerial photography. It has provided a test of how badly a remote sensor, recording between 400 and 900 nanometers, can be expected to perform at a time of the year when crop identification is known to be difficult. Almost every parameter affecting accurate category discrimination was of less than optimum condition; for example:

1. Quality of photography is highly dependent on processing and difficult to standardize for repeatability;
2. The use of coarse resolution data results in a loss of spatial resolution-related information, although color values tend to be better as shown by the results at 72 compared to 56 foot resolution cells;
3. The Bayesian decision approach classified data consisting only of color measurements, and in no way was able to incorporate the use of texture, pattern, etc. The predominant color for all Kansas agricultural crops in late July is green. There is both wide color value variation within categories and few value differences among categories. Color, therefore, was not an adequate discriminant in the present study.

The first conclusion drawn is that in Kansas, late July is not a feasible time to discriminate crops with color infrared photography. The problem is not limited to Kansas in late July, but rather is present at any locale at any time when all ground cover is essentially the same color.

While in Kansas crops are green in late July, there are, of course, other times during the year when crop discrimination would be more successful; similar situations occur in most mid-latitude agricultural regions. In the wet tropics, however, ground cover is essentially green throughout the year so that discrimination on the basis of color may prove very difficult. Furthermore, the investigation pointed to different areas of interpretation that need to be resolved.

The investigation concluded that discrimination of agricultural crops may be achieved with color infrared photography, but only after further study at time periods additional to late July.

CROP DISCRIMINATION IN THE LAWRENCE, KANSAS, AREA BY MEANS OF COLOR, COLOR INFRARED, AND MULTIBAND PHOTOGRAPHY

A. M. Neumann and D. S. Simonett
U.S. Geological Survey

This study considered the feasibility of discriminating crops in the vicinity of Lawrence, Kansas, using early-mid fall (October)

color, color infrared, and multiband aerial photography. In the statistical analyses, the performance of individual wavelength bands and various channel combinations was tested for correct crop prediction potential. It was found that individual channels or certain channel combinations gave better results than the combined channels of any of the three types of imagery for discriminating particular crops. Thus, the findings support the multispectral approach in crop discrimination studies.

For crop types, the highest average prediction accuracy was obtained when the information of all the available channels was combined. As would be expected, the percentages of correct crop prediction were higher when crop groups instead of crop types were used in the analyses. For crop groups, the color infrared photography and all channels combined gave similar high correct prediction percentages both with the Bayes program employing quantization and with the Bayes program assuming a multivariate normal distribution.

Photo interpretation tests which were conducted for crop groups on the color infrared and color photography compare favorably with the statistical results.

The results of the study were encouraging with regard to the use of automated techniques. The photo interpreter has a slight advantage over machine-obtained data in that he can make his identifications in a contextual sense. The fact that the results from both human and automated interpretation techniques are very similar shows that when high altitude photography is used, the basis for decisions becomes more comparable, that is, crop textures, heights, and patterns are exceedingly difficult to perceive for the human eye and are also not included as part of the machine process. Color is the main crop discriminant on which both types of interpretation have to rely.

When individual crop types are considered in the analyses, the results from this study are inferior to those obtained by other investigators in different agricultural environments and at different times of the growing season.

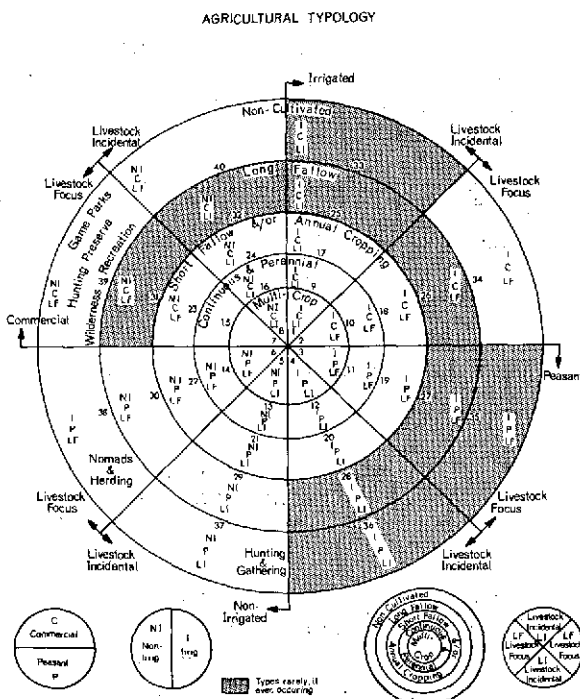
In this study, early fall does not provide better results than a previous study conducted in the Lawrence area using mid summer data. This leads to the necessity of re-evaluating the

multidate concept in crop discrimination. There may exist agricultural regions which are so composed that crop discrimination is relatively poor at all times of the year, and as a result it will not prove feasible to carry forward time-based discriminations which demand very high accessories for portions of the crop set. Mixed farming areas of great diversity in crop varieties, such as the Lawrence area, may pose considerable problems with the 3-channel RBV data in the ERTS satellites. It remains for further study to confirm whether high performing individual channels or best combinations for particular crops may reliably be used when multiple channels are available. This study lends some support to the view that this should be studied fully.

REMOTE SENSING OF TROPICAL AGRICULTURAL SYSTEMS

C. G. Knight and V. R. Harnapp
NASA

The milieu of agricultural production with which development planners must be concerned is their agricultural system, resulting from human behavior, which leaves a particular signature on the visible landscape. In



Puerto Rican Agricultural Typology Dichotomization.

order that remote sensing might provide the planner with information about agricultural systems, an interpretation model based on inferential analysis has been developed. This model focuses on fundamental landscape phenomena (element, pattern, phase) which allow interpretation of particular agricultural systems within a broad agricultural typology. The model provides keys for interpretation as well as a general analytical system for the discerning and mapping of agricultural types. Basic evaluation of the scale, resolution, and timing of remotely sensed data for maximizing benefits from information gathering in rural development applications is discussed. Application of the model is illustrated by interpretation of aerial photography from seven sample sites in the tropics—two in Puerto Rico, two in South Vietnam, and three in Tanzania.

OPTIMUM DEPRESSION ANGLES FOR GEOLOGIC APPLICATION OF RADAR

W. P. Waite and H. C. MacDonald
NASA

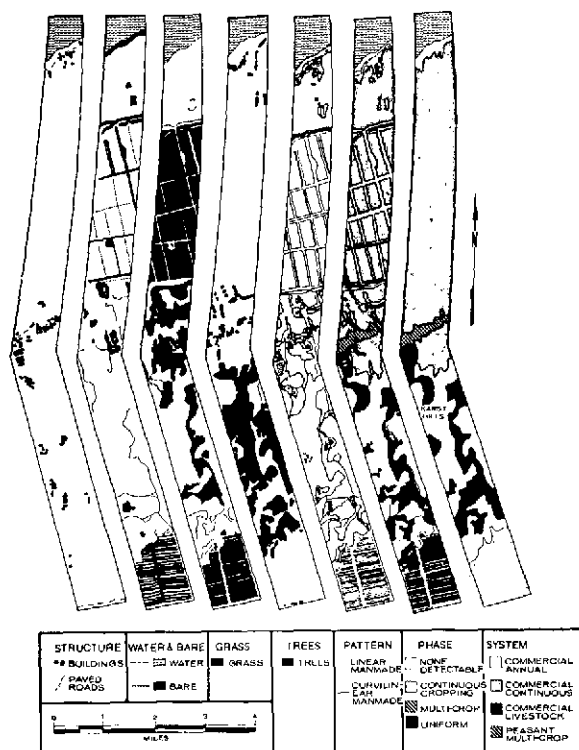
The major application of radar to geology involves recognition of structural features less easily seen on conventional photography. Because of the geometry of radar imaging, different angles of incidence are appropriate for such observations in topography with different degrees of relief. World-wide maps of optimum incident angle were prepared, based upon maps of topographic relief throughout the world.

In flat country, the geologist wishes to use radar with as shallow an incident angle as possible. The near-grazing ray causes shadows behind and bright spots ahead of small depressions. These may be used to determine lineaments and from them relate to other geologic structural features.

In areas of medium and high relief, the near-grazing radar system cannot be used because too much of the area is shadowed. Consequently, intermediate angles that approach the grazing incidence as nearly as possible without excessive shadowing must be used.

In areas of high relief, shadowing limits the maximum incident angle and layover, or distortion, limits the minimum angle. The

PALMAS ALTAS, P.R.



Analytic map of Palmas Altas, Puerto Rico.

layover occurs when the distance from radar to mountain top is less than the distance from radar to valley, even though the valley is closer along the ground to the radar track than is the mountain top. Thus, in the radar image, the mountain top appears closer to the radar and the valley farther away, when in fact, for mapping purposes, this role should be reversed. This effect is particularly severe at steep angles of incidence, so these angles cannot be used for effective imaging and interpretation in high mountains. Consequently, the high-mountain range of useful incident angles is quite restricted.

With aircraft, radar imaging in high and medium mountains has a rather restricted available swath width, because the combination of range of acceptable angles with the aircraft altitude permits only a relatively short distance along the ground. Spacecraft, however, can achieve relatively wide image swaths on the ground within relatively narrow ranges of incidence angle. Consequently, radar imaging in mountainous areas will be best when the radar can be carried aboard a spacecraft.

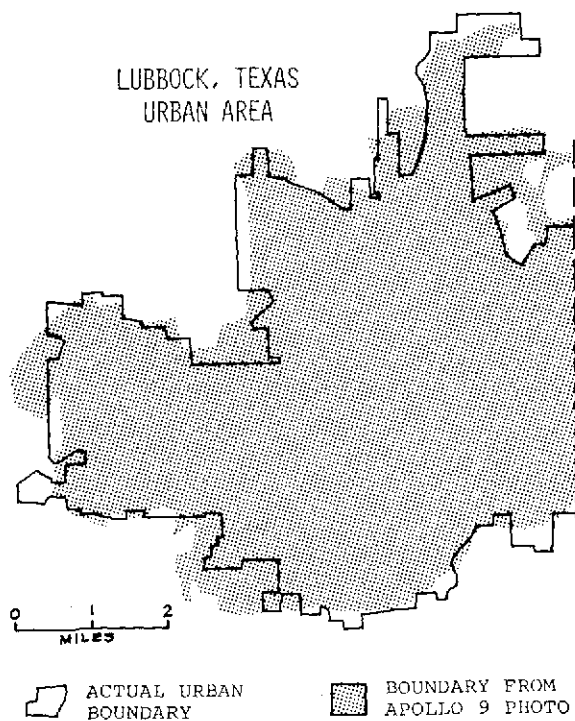
ENVIRONMENTAL FACTORS INFLUENCING THE UNIFORMITY OF SPACE PHOTOGRAPHY AS A DATA BASE FOR URBAN AND AGRICULTURAL LAND USE MAPPING

D. E. Schwarz
U.S. Geological Survey

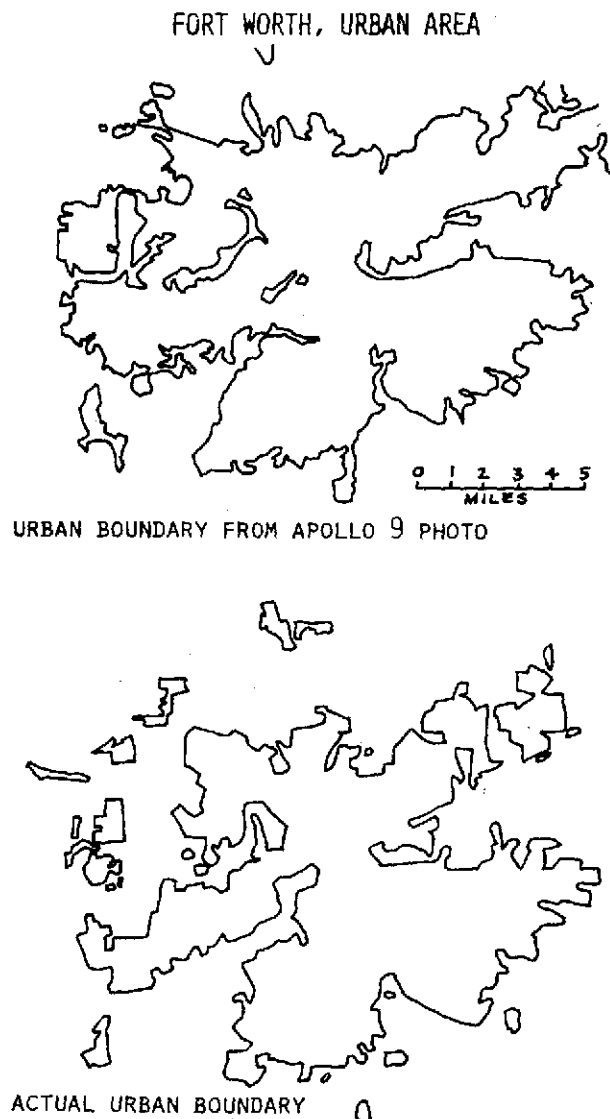
Factors of regularity, contrast, and size of the units being delimited are basic in determining how well urban and agricultural land use patterns can be interpreted from space photography. Variations in sizes of land use parcels and the resultant effect on interpretability, considering ground resolutions on the order of 250-400 feet, have been documented by Simonett and Coiner (1970). These resolutions effectively restrict interpretation of areas of normal contrast, such as agricultural fields, to those of approximately 40 acres or larger and this can be expected only where regularity of pattern and relatively high image contrasts are found. The average field sizes, even in much of the United States, are less than 40 acres.

Factors affecting contrast of environmental units are varied, and even high contrast objects must partially overcome the ground resolution barrier. Irrigated areas tend to contrast more than non-irrigated areas. Abrupt urban-rural transitions make delimitation of the urban boundaries much easier. Large blocks of trees, which may be indicative of an urban area in an otherwise mostly treeless environment, may be expected to contrast with a surrounding of grassland or cropland.

Regularity of topography, shape of land



Lubbock, Texas urban area as determined from an Apollo 9 photo compared with that taken from 1962 air photo index.



Fort Worth, Texas urban area as determined from an Apollo 9 photo compared with that taken from the map, "Generalized Land Use, Existing (1964)," Dallas-Ft. Worth Regional Transportation Study. Some distortion results from slight non-verticality of photo.

use elements, and pattern tends to enhance the probability for interpretation of agricultural or urban land use. Large fields on flat terrain with a regular, checkerboard-like pattern are ideal for interpretation. Disturbances in this pattern and in contrast and in the average size of agricultural fields bring increasing interpretive problems.

Considering only the sites studied—the Imperial Valley of California and the areas around El Paso, Lubbock, and Fort Worth, Texas, and Atlanta, Georgia—the capability for interpretation of both agricultural and urban phenomena diminished from west to east. Based on the study the following tentative conclusions are offered. Flatness of terrain is desirable. Irregularities of shape and small size of landscape elements increase interpretive problems. The mixture of woodland and cropland disturbs the interpretation. In actuality this may be in great part more a reflection of topography and its problems than of a problem of interpreting in wooded areas *per se*.

There, of course, is a climatic relationship which can be drawn. Man's uses in arid regions tend to contrast strongly with the relatively barren arid landscape. The atmosphere itself provides a lesser problem for photography. In humid areas man's works are more masked by the presence of trees and other lush vegetation. Trees, lawns, and parks in his cities do not contrast greatly with the surrounding countryside. Patches of cultivation, if large enough and regular enough, can be seen at fairly coarse resolutions, but their contrast is relatively poor in a humid environment, where the normal color is green.

It can be seen that space photography of about 250-400 feet in ground resolution cannot be expected to provide uniform urban and agricultural land use data. Continuing study into this problem will further define this data variability and will attempt to isolate the critical environmental factors responsible. Considering these results, environmental regions can be defined and mapped which indicate varying potentials for land use mapping from space, resolution requirements can be estimated for providing particular data for particular regions, and regional sampling strategies considering the relative need for spacecraft, aircraft, and surface sampling will be estimated.

THE SUSCEPTIBILITY OF ENVIRONMENTS TO LOW RESOLUTION IMAGING

D. S. Simonett and J. C. Coiner
U.S. Geological Survey

The employment of a low resolution reconnaissance system, such as the Earth Resources Technology Satellite System (ERTS), requires an investigation into the way information (desired by a potential user) is contained within an environment. It is observed that the ability of a remote sensor to provide a given element of information from a specific environment is related to the spatial and temporal complexity of the environment in which the element of information is found.

This study considered the degree of spatial (environmental) complexity in 106 county sites spread throughout the United States encompassing a wide range of environmental situations from simple homogeneous areas to complex and heterogeneous sites, and were drawn from almost every state. Thus they are reasonably representative both of U.S. environmental complexity and its areal distribution.

Each county site studied was represented by a single 9" by 9", 1:20,000 air photo acquired from the Department of Agriculture. The primary interpretation problem was to simulate low resolution imagery of 800, 400, 200, and 100 feet from the available air photo prints (1:20,000 scale, approximate resolution 6 feet). The simulation was accomplished by employing a series of 7.2"×7.2" transparent overlays, containing 225 cells of 800, 400, 200, and 100 feet, respectively. With 800 foot cells, the entire area was sampled, while for the smaller cells an areally stratified random sample was drawn within each 800 foot cell.

The actual interpretation was accomplished on the basis of categories which were originally defined for resource inventory and thematic mapping. These categories were considered in terms of the number found in each size cell, i.e., each cell had either one category, two categories, three categories, or four or more categories. The basis of comparison between county sites was the frequency of occurrence of categories, not the similarity of the categories. After the data had been interpreted from the photography, it was subjected to three clustering systems which provided

When the results of this study are applied to the stated resolutions (approximately 320 feet) for the ERTS system, it is possible to estimate the areas of greater or lesser effectiveness in terms of resolution-related information transfer for the ERTS. Based on these factors, the ERTS should be more effective for agricultural purposes in regions, such as the Great Plains, where topography, agricultural practices, and historical factors (the Homestead Acts) tend to reduce the resolution requirements for any single information category. Also ERTS will be more effective for land use thematic mapping in areas where human impact is less and where the landscape is dominated by large blocks of natural categories.

IMAGE INTERPRETATION KEYS TO SUPPORT ANALYSIS OF SLAR IMAGERY

Possible uses of dichotomous keys as aids in the analysis of SLAR imagery are being examined, with arguments directed at future remote sensing programs in agriculture and natural vegetation. For agriculture, keys are designed to determine crop types or conditions. For natural vegetation, the keys attempt to define major plant communities and ecological situations.

mation extraction from SLAR imagery. Additional research efforts are being conducted in the areas of format improvement and key automation.

**N. E. Hardy, S. A. Morain, D. D. Egbert
and F. T. Ulaby**
NASA

One possible way to analyze images of vegetation involves frequency spectral analysis of the textures present on the SLAR image. This technique is based upon the use of a coherent light source. When passed through an image of given texture, this light beam produces a characteristic Fraunhofer diffrac-

A. Field has a moderately high to high return (light grey to white on radar positive) with respect to HH)
 B. Field has a homogeneous tone (with reference to HH)
 C. Field displays a shift in tone from HH (lighter) to HV (darker)
 D. Amount of tone shift is relatively unpronounced
 E. HV tone is homogeneous ----- sugar beets or wheat > 3"
 EE. HV tone is not homogeneous ----- fallow
 DD. Amount of tone shift is relatively pronounced
 CC. Field does not display a tone shift HH(lighter) to HV(darker)
 F. Field displays a tone shift from HH(Darker) to HV(Lighter)
 G. Field has evident lineations ----- cut alfalfa
 GG. Field does not have evident lineations
 FE. Fields does not display a tone shift from HH(darker) to HV(lighter)
 BB. Field does not have a homogeneous tone
 AA. Field does not have a moderately high to high return
 H. Field has medium low to moderate return (medium dark to medium light on radar positive)
 I. Field has a homogeneous tone (with reference to HH)
 J. Field has lineations parallel to long axis of field
 K. Tone shift is evident from HH (dark) to HV (light) ----- maturing alfalfa (flood irrigated)
 KK. Tone shift is not evident
 JJ. Field does not have lineations
 L. Field displays medium coarse texture (scattered) ----- grain sorghum
 currently on HV image) (rows 1 light line)
 LL. Field has no obvious image "texture"
 M. Field has a moderate tone shift ----- alfalfa > 12"
 (HH to HV)
 MM. Field has an unpronounced tone shift ----- wheat > 3"
 II. Field does not have a homogeneous tone
 N. Cultivation pattern is observable (particularly) ----- emergent wheat
 on HV fringe)
 NN. Cultivation pattern is not observable
 O. Boundary shadowing is observable ----- mature corn
 OO. Boundary shadowing is not observable
 HH. Field does not have moderately low to moderately high return
 P. Field has very low return (very dark grey to nearly black on radar positive)
 Q. Field has a homogeneous appearance ----- recently tilled
 QG. Field does not have a homogeneous appearance
 PP. Field does not have very low return

tion pattern. Fine linear features in a vertical plane will result in a horizontal diffraction pattern, and rapid horizontal density variations will also result in high frequency horizontal patterns.

By utilizing this knowledge and by applying the technique of matched filtering, it is possible to make a statement regarding the similarity of various vegetation textures on the radar image. A final step toward completing the methodology of this rather unique

interpretation approach is the development of a series of intensity vs. θ , and intensity vs. radius curves, where θ and radius are the polar coordinates of the pattern. The intensity vs. θ curve is indicative of the directionality of the texture pattern, while the intensity vs. radius curve yields information about the frequency (i.e., fineness or coarseness) of the texture pattern. Ideally, these curves will be unique for each structural category displayed on the imagery.

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1969-1971 MASTER'S DEGREES AWARDED

AEROSPACE ENGINEERING DEPARTMENT

Rex D. Agler	Experimental Investigation of the Influence of Wing and Spoiler Geometry on Spoiler Effectiveness for Light Aircraft
William R. Capron	An Artificial Force-Feel System for a Fixed-Base Flight Simulator
Robert C. Colwell	Improvement of the Performance Stability and Control of a Current Light Aircraft
Samual A. Henry	Non-thesis
Tian-Lai Hu	Non-thesis
Sudhir Mehrotra	A Computer Program for Calculating an Aerodynamic Influence Coefficient Matrix for Thin Wings at Subsonic and Supersonic Speeds
Kapil Kumar Nanda	Non-thesis

CHEMICAL AND PETROLEUM ENGINEERING

Chemical Engineering:

Pradcep Beri	Activation of Petroleum Coke
Ugersain Chopra	Investigation of Surface Temperature Drops During Nucleate Boiling of Water and Binary Mixture on Pyrex at Atmospheric Pressure
Hassan E. Dabiri	Numerical Modeling of Unsaturated Ground-Water Flow
Neil H. Drake	A Computer Study of a Discrete Gradient Optimization Methods as Applied to Topologically Exact Models
Gary P. Emery	Dynamic Effects of Growth Variables on Solute Distribution in Czochralski-Grown Single Crystal Silicon
Kuo-Hsin Fan	Application of the Recycle Reactor to the Solid-Catalyzed Isomerization of Cyclohexane
Kelvin W. Flory	An Experimental Study of Sodium-Water Explosions
Gregory J. Gauthier	Parameter Optimization in a Mathematical Model for Mass Transfer in Two-Phase Flow
Safaa Fahmy Mohamed Ghoneim	Experimental Determination of Overall Mass Transfer Coefficients for Desorption of Ammonia from Water at Low Concentrations in Packed Towers, and the Effect of Carbonate Ion on the Mass Transfer
Ravinder Kumar Goel	Measurement of Surface Temperature Fluctuations During Nucleate Boiling of Water and Toluene Using a Thin Film Resistance Thermometer on Pyrex
Victor Manuel Hernandez Infante	The Adsorption Front: Dynamics and Simulation
Jose Rafael Gutierrez Jaramillo	Permeability and Separation of Gases Through Hollow Membranes
Paul S. Offutt	An Investigation of the First and Second Collapse and the Migration of Non-Hemispherical Vapor Bubbles on Solid Boundaries
Carlos Suarez	Computer Program for the Determination of the Optimum Size or Optimum Performance of a Reactor-Separation Modulus
Thomas W. Yergovich	Low Temperature Viscosities and Densities of Methanol-Water and Aceton-Water Solutions

Petroleum Engineering:

S. R. Hasnain	Optimal Scheduling of Portable Gas Compressors
Jitendra D. Khare	Test and Application of a Computer Model Describing Unsaturated Ground Water Flow in the Presence of Evapotranspiration
Roy M. Knapp	A Dynamic Investigation of Sucker-Rod Pumping
Braj Nandan	An Automatic History Matching Procedure for Use in Mathematical Modeling of Hydrocarbon Reservoirs
Owen T. Spitz	Use of Production Data to Predict Future Crude Oil Production and Ultimate Reserves

CIVIL ENGINEERING

Civil Engineering:

Katharine Man-Ying Chan	Non-thesis
Alan James Geery	Non-thesis
Allen Heyson Gipson, Jr.	Controlled Rate of Strain Testing of Undisturbed Soil Samples
Joseph John Gurda	Settlement of a Partially Saturated Compacted Fill
Wasi-Ahmad Hanafi	Non-thesis
Mao-Ching Huang	Non-thesis
Charles A. Lagergren	Non-thesis
Samuel L. Love	A Substructure Approach to Space Truss Analysis Using the Flexibility Method
Bruce Frank McCollom	Non-thesis
James Donald Mount	Non-thesis
Abhay Balkrishna Naik	Non-thesis
James William Orr	Stress Analysis of a Soil Material Foundation
Jayanti D. Patel	Shear Centers for Thin-walled Members
James Wallace Peck	Application of Fracture Mechanics Theory to Fracture Behavior of a High-Strength Aluminum
Carl B. Reed	A Literary Survey on Low-Cycle Fatigue of High Strength Steel
Robert Harold Schorn	Frame Analysis by the Stiffness Method Using Substructures
Edward Sture	Non-thesis
Ricardo Bozzoli Vargas	Non-thesis

Environmental Health Engineering:

Robert Miles Appleberry	Non-thesis
Robert Burns Barbour	The Effect on the Effluent Quality of an Activated Sludge System Caused by Short Periods of an Aerobic Condition in the Aeration Tank
L. R. Duvall	Non-thesis
Carl L. Hamann, Jr.	A Study of Up-flow Filtration
Robert Joseph Koke	Non-thesis
Neal R. Kuehl	Non-thesis
Oren O. Long	General Agricultural Pollution—Its Dimensions and Reduction Possibilities
Chilton White McLaughlin, III	Modeling of an Oxidation Ditch System for Treatment of Swine Waste
William R. Park	Non-thesis
Ronald R. Ritter	Non-thesis
Frank Lavern Shorney	Non-thesis
Theodore W. Stackley	Non-thesis
Gerald Arthur Stoltenberg	Indicator Organism, Oxygen Levels, and Fertilizer Components in a Farmland Stream
Martin Trnovsky	Non-thesis

Environmental Health Science:

Donald Craig Draper	Non-thesis
Wayne Eric Johnson	Use of Lime-Soda Ash Softening Sludge for the Treatment of Municipal Waste Water
Donald M. Martin	Several Methods of Algae Removal in Municipal Oxidation Ponds
Pamela K. Mintz	Analysis of the Cooperative Farm Chemical Association's Effluent: A Case for Pollution Control
Christina R. Palmerlee	Effect of Temperature on Substrate Removal in Activated Sludge
Diann Taylor Schwegler	An Evaluation of Microbial Indices in Various Wastewaters
Alex Aristotelis Thomopoulos	The Validity of Using Pure Oxygen in Wastewater Treatment

Water Resources Engineering:

Larry Daniel Black	A Preliminary Investigation of a New Approach to Calculating Flood Frequencies
I-Lung Cheng	Non-thesis
Ivan Charles James, II	Interstation Correlation and Information Content in Rainfall and Flood Peak Runoff
Donald F. Kostecki	Evaluation of Methods for Estimating Daily Potential Evapotranspiration
Gyula F. Kovach	Non-thesis
Frederick Adrian Perrenot	Considerations of the Flood Insurance Program
Norman Wahl Scheffner	A Two Phase Approach to Development of Runoff Hydrographs for Small Urban Basins
Eric P. Yould	An Infiltration Approach to Surface Runoff

Engineering Mechanics:

John R. W. Bales	Non-thesis
Tony Chung-Li Chen	Non-thesis
Sherman Chieh	Non-thesis
John E. Holcomb	Non-thesis
James Nelson Ingram	An Experimental Investigation of the Elastic Stability of Simply Supported Corrugated Diaphragms Loaded in Pure Shear
Kuang Hsiu Lu	Non-thesis
Richard Robert Moderow	Vibration Characteristics of Steel Joist-Concrete Slab Floor Systems
William Howard Nsubuga	Influence of Fasteners on the Behavior of Shear Diaphragms

ELECTRICAL ENGINEERING

Adil Ali Abdul-Rahman	Non-thesis
Robert M. Axline	Non-thesis
Percy P. Batlivala	Non-thesis
John Wesley Cain, Jr.	Use of MOS Capacitors for Transistor Process Evaluation
Ignacio A. Caverio N.	Non-thesis
Rakesh Chandra	Non-thesis
Chin-Huang Chen	Non-thesis
Peter Cheng Chen	Non-thesis
Pijush Kanti Deb	Non-thesis
Hans Dodel	Non-thesis
Jimmy Earl Dumas	Non-thesis
Kayode Edun	Non-thesis
Dwight David Egbert	Spectral Reflectivity Data: A Practical Acquisition Procedure
Gary Engmann	Non-thesis
Abdul Ghafoor	Non-thesis
Martin L. Grogan	Non-thesis
Parveen Kumar Gupta	Interface of PDP-15/20 and 201A1 Data Set
Raymond K. Ho	Non-thesis
Mokshagundam Jayaram	Non-thesis
Rameshchandra P. Jethva	Non-thesis
Ashok Kumar Kamra	Non-thesis

Hong-Ki Kang	The Plasma Frequency Reduction Factors in Relativistic Brillouin Beams of High Power Klystrons
Wirush Kasemratanasunti	Replacement of a Band-Limited Gaussian White Noise By an Infinite Bandwidth Gaussian White Noise Through Statistics Matching
Shahid Farooq Khalid	Non-thesis
Mohan Lal Khetarpal	Non-thesis
Cheng King	Non-thesis
R. Kuppuswami	Non-thesis
Uttam Lall	Non-thesis
Ramesh P. Lulla	Non-thesis
Omar Mardam-Bey	Non-thesis
Gary D. Moser	Non-thesis
Mudduveerappa	Non-thesis
George Nossaman	Imaged Textural Analysis By a Circular Scanner Technique
Surendra Kumar Parashar	Interface of PDP 15/20 Computer with Magnetic Tape
Jashbhai J. Patel	Non-thesis
Thomas E. Polcyn	Non-thesis
D. N. Raju	Non-thesis
Gummaraju Ramaswamy	Non-thesis
P. Pandu Rangam	Non-thesis
Hassan Razaghi-Khamsi	Non-thesis
Rodda R. Reddy	Non-thesis
Brandon N. Reed	A Study of An Ideal Switch Used as a Mixer
Simon A. Ruiz	Non-thesis
Anupam Sachdev	Non-thesis
Surendra Kumar Salgia	Non-thesis
Bipin R. Shah	Non-thesis
Yogesh Chandulal Shah	Non-thesis
Hung Sung Shih	Non-thesis
James A. Smith	Non-thesis
Mohammad Taleghani	Non-thesis
Gopal Krishna T. K.	Non-thesis
S. Vetrivelayudham	Non-thesis
Ching Ih Wang	Non-thesis
Gary Lee Wright	Non-thesis
James Douglass Young	Non-thesis
Jalil Zarraby	Non-thesis

MECHANICAL ENGINEERING

Orlando Ayala	Non-thesis
I-Shih Chang	Non-thesis
Disya Chayaniyayodhin	Non-thesis
Hasavantray D. Doshi	Non-thesis
Kenneth M. Frost	Probable Error in Statistical Analysis
Ramesh C. Garg	Non-thesis
Nanak S. Grewal	Non-thesis
Jeewankumar S. Kapale	Non-thesis
Maruti N. Kendale	Non-thesis
Ramakrishna Koduri	Non-thesis
Chanchai Limpiyakorn	Non-thesis
Harshadraj S. Modi	Non-thesis
Nipat Pitayanuvath	Non-thesis
Vinayakara Rao	Study of the Phenomenon of Internal Damping in a Cantilever Beam Made of SAE 1020 Steel
Mulchand K. Shah	Non-thesis
Jasvir Singh	Non-thesis
Bill C. Tompkins	Design of a Representative Liquid Fuel Launch Vehicle Model to Demonstrate the POGO Phenomenon
Mayukh T. Trivedi	Non-thesis
James W. Van Kirk	An Incompressible Flow Analysis of Spring Loaded Gas Compressor Valves
Krishnasa Walvekar	Non-thesis
Pinyo Wichayapinyo	Non-thesis

1969-1971 DOCTOR OF PHILOSOPHY DEGREES AWARDED

CIVIL ENGINEERING

Engineering Mechanics:

Mahendra Kumar Bansal	Dispersion and Reaeration in Natural Streams
Henry Morgan Dodd, Jr.	Empennage Loads on T-Tail Transports in Continuous Atmospheric Turbulence
Ronald George Merritt	Parametric Resonance of Skew Stiffened Plates
Thomas M. Murray	Application of Direct Energy Minimization to the Static Analysis of Cable Supported Structures
Everett Howard Prewitt	Parametric Instability of Stiffened Cylindrical Panels
William F. Teague	A Steepest-Descent Algorithm for Minimizing Sensitivity of Optimal Systems to Variations in Their Parameters

Environmental Health Engineering:

Sanford MacLean Brown	The Establishment of a Sanitary Landfill for Lawrence, Kansas
Michael J. Chun	Oxygen Response of Completely Mixed Activated Sludge Systems with Sludge Return to Transient Organic Loading
Corbin E. McGriff, Jr.	Nutrient Removal of Activated Algae
Jerome Linn Mahloch	An Investigation of the Microbiology of Aerobic Decomposition of Refuse
Daniel Walter Smith	Modelling Oxygen Transfer in Diffused Aeration Tanks
John Randall Stukenberg	Carbon 14 Tracing of Endogenous Metabolism
Timothy Tilsworth	Aerobic Surface Stabilization of Refuse

CHEMICAL AND PETROLEUM ENGINEERING

Chemical Engineering:

Surjit S. Chhatwal	An Investigation of the Centered-in-Distance, Centered-in-Time Methods for Solution of the Convection-Diffusion Equation for Liquid-Liquid Miscible Displacement in Porous Media
Michael Cheng-Shung Chen	Analysis of Entrance and Exit Effects in a Falling Cylinder Viscometer
Charles R. Clark	Adsorption and Desorption of Light Paraffinic Hydrocarbons in Dry and Water-Saturated Sand-Clay Packs: Studies to Determine the Effect of these Phenomena on the P-v-T Behavior of Natural Gases and Gas Condensates in the Reservoir
Ronald L. Cox	The Method of Characteristics Solution to a Two-Dimensional Mathematical Model of Liquid-Liquid, Miscible Displacement in Porous Media: An Evaluation by Comparison of Mathematical and Experimental Results
Hassan E. Dabiri	Digital Simulation of Unsaturated Ground-Water Flow Considering Evapotranspiration
William B. DeAtley	A Study to Determine the Feasibility of Using Statistical Expectation to Improve the Control of a System Being Upset with Random Step Inputs of a Known Distribution
Francis J. Eichstadt	The Degradation of Drag Reducing Additives in Turbulent Pipe Flow
Norman W. Green	An Experimental Study of the Microshock Pressure Pulses and Small Vapor Bubbles Generated by the Collapse of a Larger Vapor Bubble in Water

- Un Kyung Im Solubility of Solid Carbon Dioxide in Certain Paraffinic Hydrocarbons: Binary, Ternary and Quaternary System
- Robert H. Jensen Heterogeneous Phase Behavior of Solid Carbon Dioxide in Light Hydrocarbons at Cryogenic Temperatures
- James P. Kennedy Optimal Simulation and Control of Dynamic Systems Using a First Order Prediction of the Objective Function with Experimental Verification of the Simulation Technique Applied to a Heat Transfer Vessel
- S. Madhavan An Experimental and Mathematical Study of the Shapes of Bubbles Growing on Surfaces in an Isothermal Superheated Liquid
- David B. Manley Relative Volatility of the Propane-Propene System
- Kenneth L. Mulholland An Empirical Study of the Benedict, Webb and Rubin Mixture Rules and Experimental Vapor-Liquid Data for the Binary Methane-N Butane
- Robert H. Smith A Photographic Study of the Influence of an Air Bubble on the Growth and Collapse of a Vapor Bubble in Water
- Charles E. Stofer A Discrete Gradient Optimization Algorithm for the On-Line Determination of Parameters of Process Models
- James D. Walker Dense Fluid Viscosity and a Correlation Based on the Square-Well Potential Function for Ethane and Three Mixtures of Methane and Ethane
- Maung Maung Win An Experimental Verification of Similarities Between Dye Removal and Clay Soil Removal from Cotton by Non-Ionic Detergents

Petroleum Engineering:

- John F. Evers Design and Operation of a Laboratory Model to Study Unsteady-State Radial Gas Flow in Porous Media

ELECTRICAL ENGINEERING

- Phillip Edward Allen Extension and Generalization of RC Active Network Methods
- James Rowland Andrews Deflection Theory of Traveling Wave Oscilloscopes
- William D. Boles Scattering of Waves From a Rough Layer
- G. A. Bradley Remote Sensing of Ocean Winds Using a Radar Scatterometer
- Ralph Walter Gershberg Synthetic Aperture Radar and Digital Processing
- Alfred P. Gnadinger Surface Mobility Near Threshold and Other Parameters of Insulated Gate Field Effect Transistors
- Robert Martin Haralick Multi-Image Pattern Recognition
- John Neal Latta Computer-Based Analysis of Holography
- Han Liang Lee Range Error Statistics of a Satellite Radar Altimeter
- Anthony Michael C. Leovaris Theoretical and Experimental Study of Wave Backscattering From an Irregular Thin Lossy Layer
- James A. Lucas A High Speed Disc Memory and A Color Image Display For A Small Computer
- Virendra K. Manaktola Minimization of Sensitivity Over a Frequency Interval and Synthesis of Electrical Networks with Practical Parameter Constraints
- Charles Henry Manney, Jr. The Frequency and Time Domain Transmission Responses of Coaxial Lines Having Semi-Solid Dielectric Structures
- James Donald Pauley A Pulse Modulated Biotelemetry System For Monitoring Heart Rate and Body Temperature in Free-Ranging Vertebrates
- Charles Clinton Schooler, Jr. Optimal and Suboptimal Control Problems With Q-TH Order State Inequality Constraints
- Gary C. Thomann Panchromatic Illumination For Radar: Acoustic Simulation of Panchromatic Radar
- Robert C. M. Tu Scattering From Inhomogeneous Media
- William Porter Waite Broad-Spectrum Electromagnetic Backscatter

1970-1971 DOCTOR OF ENGINEERING DEGREES AWARDED

Dennis Cannon	The Aerodynamic Analysis and System Synthesis for a Light Airplane with Spoilers
Hassan Dabiri	Digital Simulation of Unsaturated Ground-Water Flow Considering Evapotranspiration
Terry Faddis	The Development of a Pseudo Homogenous Three-Dimensional Composite Material
Frank Gordon	Fabrication and Analysis of Tetra-Core: A Layered Anisotropic Fiber Composite
Larry Harper	An Operations Manual and Project Report of a Fixed-Base Flight Simulator for General Aviation Airplanes
Parviz Kiankhooy-Fard	The Photographic Display Apparatus with Free-Format Response Detection and Programmable Advance
Bill Tompkins	Design of a Representative Liquid Fuel Launch Vehicle Model to Demonstrate the POCO Phenomenon
James Van Kirk	Design of an Automatic Dynamic Balancer for a Vertical Axis Washing Machine